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A FIVE-YEAR DENDROMETER RECORD IN TWO TREES OF PINUS STROBUS

By Ray C. Friesner and Gershom Walden

So far as is known to us there is no published account of a dendrometer record of white pine growth behavior. Brown (2) studied growth behavior and cambial activity using the histological method; Goldthwait and Lyon (5) studied secondary growth in relation to water supply, using annual ring width as the criterion of growth; Hastings (7) studied time and position in the tree when initiation of diametral increase began; Henderson, Brown and Mac Kay (8), using borings, studied growth rate in relation to size of tree and character of stand; Lyon (12) used annual rings from sections of trees felled by the New England hurricane of September 1938; and Priestley (14) comments on initiation of cambial activity in conifers in general; but we are aware of no published dendrometer record.

METHODS AND MATERIALS

Dendrometers, secured from Dr. D. T. MacDougal, were attached to two trees of *Pinus strobus* located at 1 Simonton Road, Camden, Maine, on March 1, 1941. Each dendrometer was attached to the trunk of its tree approximately 4.5 feet from its base. These trees stood on the edge of a cleared field about 200 feet northeast and a similar distance southeast (respectively) from a dwelling and garage. They were about 195 feet apart. Each tree was associated in a small clump with a few other trees. On March 16, 1946, tree A measured 74 inches and tree B 61 inches in circumference at breast height. Weekly readings were made from the time of installation until March 30, 1946.

Meteorological data were supplied by the U. S. Weather Bureau, New England Section. Rainfall data for the period, March 30 to October 1, 1941, were taken at Gardiner, a distance of about 40 miles west. This was the nearest station at that time. After this date, rainfall data were secured at Rockland, a distance of about 10 miles away. Temperature data for 1941 were taken at Winslow, a distance of about 40 miles northwest; those for subsequent years were taken at Rockland.

The lever arms of the dendrometers had a ratio of 1:25 which means that each space on the dendrometer scale was equivalent to 0.04 mm and that readings could be made to the nearest 0.01 mm by estimating fractional portions of the scale. Dendrometer indicators were reset as often as necessary and were kept in good working condition at all times. Otherwise, they were not changed throughout the five-year period. Complete data are presented in table I.

INITIATION OF RADIAL ENLARGEMENT

Brown (2), using the histological method, reported two types of "growth" in white pine, viz., "growth without cell division" and "growth by cell division." The former occurred in the phloem and was reported by him to be due to rise of soil water due to increase in temperature. The latter is due to cambial activity in which new elements of wood and phloem are formed. In the light of our data it seems that Brown's "growth without cell division" is really only a rehydration recovery of radial enlargement from losses due to dehydration following the maximum radial expansion of the preceding season.

We have considered the time of initiation of true radial enlargement to be the time when the radius begins to exceed the maximum length reached during the preceding season. We have thus allowed for the recovery of losses sustained between the time of maximum radial enlargement of the preceding season and the complete recovery during the current season. Examination of the data presented in table I will reveal that true radial enlargement began in tree A during the weeks ending: May 2, 1942; May 22, 1943; April 15, 1944; and May 26, 1945. In tree B true radial enlargement began during the weeks ending: May 2, 1942; May 15, 1943; April 29, 1944; and May 5, 1945. These data are summarized in table II.

Temperature appears to be the most important limiting factor of the complex of external factors controlling time of initiation of radial enlargement. In table III are given the maximum, minimum, and mean daily temperatures for May and April of each year. Comparison of dates of intiation of radial enlargement in tables I and II with the data of table III reveals that, except for tree A in 1944 and tree B in both 1944 and 1945, the date of initiation of radial enlargement falls from 1 to 20 days after the mean daily temperature reaches 50° F. and remains there essentially continuously. Since our dendrometer records were taken only once per week, the exact number of days elapsing between the date when the mean daily temperature reached 50 and the time of initiation of radial enlargement cannot be determined. Six days could be added to the minimum number of days or subtracted from the maximum number of days given above. (See columns 10 and 11 in table II.)

Brown (2) found that cell division in *Pinus strobus* began in three out of four cuttings made five days after the mean daily temperature had reached 52° F. Cell division had reached the base of the trunk within 13 days after the mean daily temperature had reached 52.

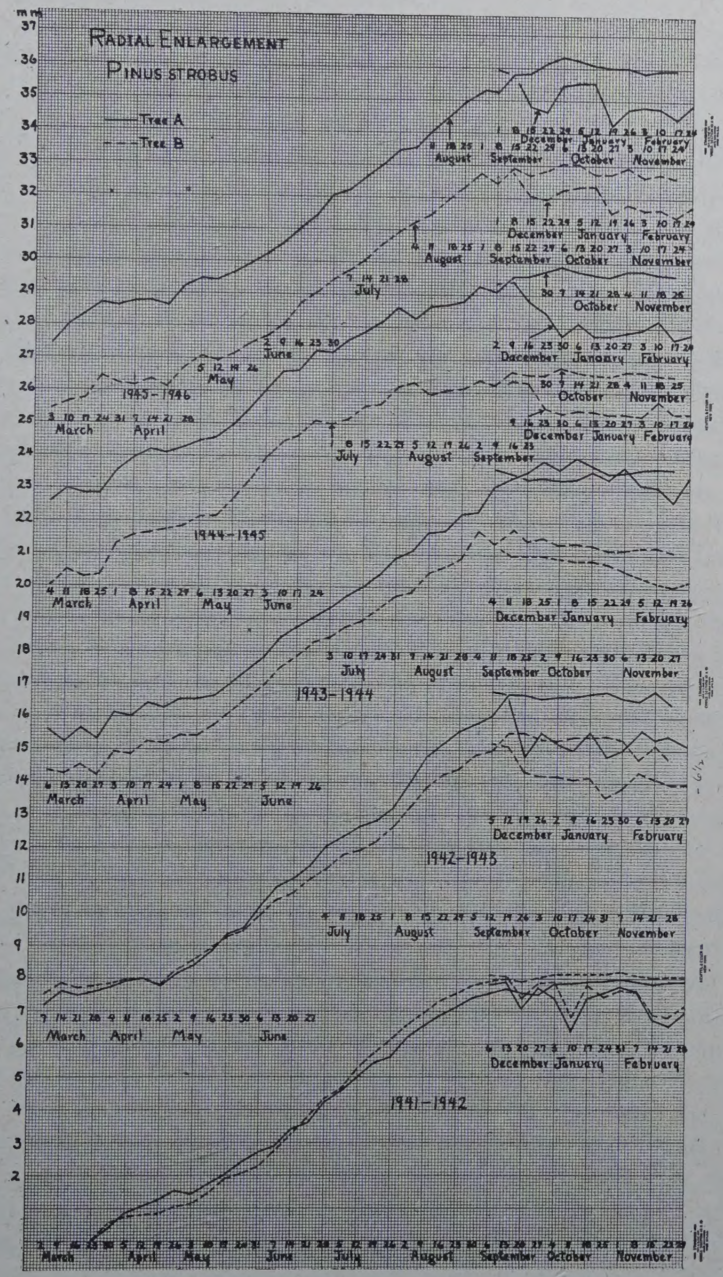
In 1944, both trees A and B, and in 1945, tree B (table II, columns 10 and 11) true radial enlargement apparently began from 1 to 21 days before the mean daily air temperature reached 50. Because of the time interval between readings, these days might be reduced to 1 to 7 for the first and to 15 to 21 for the second of these readings. We are at loss to explain why tree B was so much earlier in the time of its initiation of radial enlargement than tree A in 1945.

In 1942 initation of radial enlargement in the trunk at the point where the dendrometers were attached came one week after the terminal buds began to swell. In 1941, if our method of arriving at the time of initiation of radial enlargement(since we did not have data revealing exactly when recovery from previous shrinkage was complete) is correct, initiation of radial enlargement came during the same week when the terminal buds began to swell. Observations on time of swelling of buds were, unfortunately, not recorded for 1943-1945. Hastings (7) found that in *Pinus strobus* first new wood appeared on 2- and 3-year twigs just as the buds were beginning to swell. By the time buds were well opened it had extended down the trunk. He found that in hemlock, which holds its leaves up to 6 or 7 years, diametral increase reached its peak in rate earliest in 6-year branches. Wight (16) found that growth in the trunk of the Scotch pine (*Pinus sylvestris*) begins suddenly and uniformly throughout its length, closely correlated with the beginning of bud activity. Buds all over the tree began growth simultaneously. Growth activity of buds over the entire contour of trees of white pine (*Pinus strobus*) and red pine (*P. resinosa*) has been shown to occur within a two-day period (Friesner, 4). Rees (15) found that cell division of the cambium in red spruce (*Picea rubra*) came in late May and early June coincident with swelling of cone buds, two to three weeks before initiation of activity of vegetative buds.

Korstian (10) found that diametral enlargement began in the blue spruce (*Picea parryana*) coincident with beginning of bud activity. Growth was already under way when his dendrograph was attached and this was about the time of bursting of the buds. Priestley (14) has pointed out that the protoplasm of the cambium changes from a granular gel to a swollen, semifluid sol condition prior to the beginning of cell division and that, while in the dicotyledons considerable time may elapse between initiation of cell division in buds and its initiation in the cambium at the base of the trees, in conifers cambial activity in trunks may follow much more closely that of the buds.

MacDougal (13) points out that rising temperature alone does not serve to awaken dormant cambium. The fact that cambial activity begins (*Pinus strobus*) all over the tree within the course of a few days after the beginning of bud activity is in keeping with the conception of hormonic control of growth by auxins originating in the buds. The extent of this hormone control has not been determined, but in cases where buds have been removed during the preceding season cambial activity fails. Haasis (6), in summing up the data regarding correlation of radial enlargement with other activities, concludes that in gymnospermous evergreens the radial enlargement, at the level in the trunk where dendrometers and dendrographs are usually attached, begins shortly after the buds begin to swell.

The time when true radial enlargement began in 1941 cannot be determined certainly because we have no way of knowing exactly when recovery from previous shrinkage was complete. Our method of calculating the dates given in table II for 1941 is as follows: (1) determine the average amount of radial increase (for each tree separately) occurring between March 1 and the time when recovery was complete in the years when the time of complete recovery is certainly known. (2) The time when the above average amount of radial increase had occurred after March 1, 1941, was chosen as the time for beginning of true radial enlargement for that year.


RADIAL ENLARGEMENT
PINUS STROBUS
Tree A
Tree B
mm
37
36
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34
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4
3
2
1945–1946
1944–1945
1943–1944
1942–1943
1941–1942
3 10 17 24 31 7 14 21 28
March April
5 12 19 26
May
2 9 16 23 30
June
7 14 21 28
July
4 11 18 25 1 8 15 22 29 6 13 20 27 3 10 17 24
August September October November
1 8 15 22 29 5 12 19 26 3 10 17 24
December January February
4 11 18 25 1 8 15 22 29 6 13 20 27 3 10 17 24
March April May June
1 8 15 22 29 5 12 19 26 2 9 16 23
July August September
30 7 14 21 28 4 11 18 25
October November
2 9 16 23 30 6 13 20 27 3 10 17 24
December January February
6 13 20 27 3 10 17 24 1 8 15 22 29 5 12 19 26
March April May June
3 10 17 24 31 7 14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
July August September October November
4 11 18 25 1 8 15 22 29 5 12 19 26
December January February
7 14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
March April May June
4 11 18 25 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28
July August September October November
5 12 19 26 2 9 16 23 30 6 13 20 27
December January February
2 9 16 23 30 5 12 19 26 3 10 17 24 31 7 14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 27 4 11 18 25 1 8 15 22 29
March April May June July August September October November
6 13 20 27 3 10 17 24 31 7 14 21 28
December January February

RATE AND AMOUNT OF RADIAL ENLARGEMENT

Reference to table I and figure 1 reveals that the rate of radial change was irregular from week to week in both trees and for all five of the seasons for which data are available. Brown (2) concluded that there are two periodic optima of "growth" in *Pinus strobus*: one during May and early June, and the other in July and August. Our data do not reveal such optima.

Seasonal shrinkages due to dehydrations of more than diurnal extent, such as noted by Haasis (6) to occur in all species studied by him, were found to occur during the enlarging season for one or more weeks for both trees A and B, for each season for which we have data. Reference to table I and figure 1 will show that only once (September 20 and 27, 1941) for tree A, and at no time for tree B, were these shrinkages of more than one-week duration. Shrinkages and recoveries were numerous during the dormant season for both trees and for all years. During the dormant season shrinkages of over 1.00 mm in radius occurred a number of times but in all cases they were correlated with large temperature drops. They continued for a number of weeks with recovery in some cases occurring only gradually while in other cases recovery was as sudden as the shrinkage. A striking case is found during the weeks ending January 3 and 10, 1942. Shrinkage of 1.00 mm in tree A and 1.04 mm in tree B during the first of these two weeks is followed by complete recovery during the second of the two weeks and this is correlated with an on-the-spot thermometer reading of —42° F. on January 3 and 42° F. on January 10. The maximum radial shrinkage noted was 1.92 mm in tree A during the week ending December 19, 1942. Tree B showed a radial shrinkage of only 0.80 mm during the same week.

Whether these extreme hiemal changes are due to a combination of wood contraction resulting from low temperature and bark contraction due to water loss resulting from inability of roots to secure water from frozen soil to replace that lost by transpiration, has not been determined.

Reference to table I will show that the radius of tree A enlarged 6.56 mm in 1941; 8.80 mm in 1942; 7.18 mm in 1943; 5.90 mm in 1944; and 6.44 mm in 1945. Tree B showed radial enlargement of 6.98 mm in 1941; 7.29 mm in 1942; 6.27 mm in 1943; 5.00 mm in 1944; and 6.28 mm in 1945. Amounts of radial enlargement and percentages of 6-year average of annual rainfall show a fair degree of correlation. In 1942, when the annual rainfall was 101.95% of the 6-year average, radial enlargement showed a significant increase as compared with the previous year when the annual rainfall was only 70.05% of the 6-year average. In 1943, when annual rainfall increased to 114.56% of the 6-year average, radial enlargement was less than the preceding year which, as stated above, had approximately the 6-year average rainfall, and this decrease in radial enlargement is in spite of the further fact that during 1943 rainfall for the chief growing season (May-August) was 153% of the 6-year average for that period.

In 1944 and 1945, when annual rainfall was 95.28% and 103.96% respectively of the 6-year average, and the May-August rainfall was 62.7% and 137.5% of the 6-year average, strong correlation with radial enlargement is shown. It is to be expected that correlation will be stronger in years when rainfall is below average, or when it changes from below average to above average. This was found to be true for deciduous trees in Indiana (3). The greatest amount of radial enlargement was found in both trees in 1942, when total annual rainfall and that for May-August was nearest the 6-year averages. Goldthwait and Lyon (5) found that May-July rainfall is the dominant element in the factor complex of climatic factors related to growth. They found that white pine and hemlock were quite similar in their response to the dominant factor of rainfall. Lyon (5), in a later paper, found that white pine showed a positive correlation between growth and rainfall for various combinations of months and also for temperature of the early spring.

Total radial enlargement for the 5-year period was 34.88 mm in tree A and 31.82 mm in tree B. This is an average of 6.97 mm and 6.36 mm per year respectively. It must, therefore, be concluded that these trees were vigorously growing. These data are summarized in table II.

DURATION AND CESSATION OF RADIAL ENLARGEMENT

Radial enlargement was considered to have ceased at the time when the maximum length of the radii were attained for each season. This time for tree A ranged from October 6 to November 1; and for tree B from September 18 to November 1. Tables I and II show these data. It is not likely that actual cell division continued until these dates. It is more probable that cell enlargements, following divisions which ceased earlier, account for the radial enlargements of the final weeks. Brown (2) found that xylem formation continued in all parts except the terminal leader, until late September or early October at Ithaca, New York. Phloem formation continued into October. While growth is first retarded in the upper parts of the tree, the final cessation occurs nearly simultaneously throughout.

Temperature is probably the limiting factor in most cases controlling the time of cessation of cell division. Since no prolonged or marked shrinkage occurred simultaneously in both trees within a month before cessation of radial enlargement, it is not likely that rainfall as such played a prominent rọle in determining the date of cessation. Priestly (14) considers that, in tree trunks generally, cessation of cambial activity is often determined by water deficit. As this deficit increases, air replaces the water in the large and numerous air spaces in the rays of dicots and cambial growth ceases. It, however, may begin again when the air is displaced by water, provided other conditions are favorable. In conifers, where air spaces are smaller, cambial activity is more independent of fluctuations of water supply. Since there was considerable difference between the two trees in regard to time of cessation of activity, especially in 1942 and 1943 (table II), it is likely that time of cessation is also dependent upon some internal factors which do not always correlate so closely with temperature. Brown (1) found in *Pinus resinosa* that while there is considerable uniformity among different individual trees in the time of beginning of cambial activity, there is no such uniformity in regard to the time of cessation of activity.

Referring the cessation dates shown in table I and tabulated in table II to the temperature data for the months of September and October given in table V shows no consistent discernible correlation between temperature and time of cessation. In 1941, when both trees reached their maximum radial enlargement during the week ending November 1, the mean daily temperature had fallen below 50° F. on 22 different days before this cessation time. During 1942, when the maximum radial enlargement was reached in tree A during the week ending October 31, but had been reached in tree B six weeks earlier, there were 18 days during which the mean daily temperature fell below 50° F. before tree A ceased to enlarge. Tree B, on the other hand, ceased to enlarge 9 days before the mean daily temperature reached as low as 50° F. The mean daily temperature fell below 60° F. on only six days before tree B ceased to show radial enlargement in 1942. Again, in 1943, tree B ceased to show radial enlargement some time before tree A ceased. In this case the mean daily temperature fell below 50° F. on ten days before tree A ceased while tree B ceased one day before the mean daily temperature reached 50° F. for the first time and eight days before it reached 50° F. for the second time for that season.

In 1944 and 1945 both trees ceased radial enlargement during the same week, viz., during the week ending October 7 in 1944 and October 6 in 1945. In both years there were eight days during which the mean daily temperature fell below 50° F. before enlargement ceased.

That *Pinus strobus* is a long-growing species seems clear from our observations. Radial enlargement continued for a total of from 20 to 28 weeks in tree A and from 17 to 27 weeks in tree B. There was no correlation between the number of weeks of radial enlargement and the amount of radial enlargement. Tree A showed greater radial enlargement in 22 weeks in 1943, when rainfall was 114.56% of the six-year average than it did in 28 weeks in 1941 when rainfall was only 70.05% of the six-year average. It showed only 0.12 mm less radial enlargement in 20 weeks in 1945, when rainfall was 103.96% of the average, than in 28 weeks in 1941, when rainfall was only 70.05% of the average. Similar relationships pertain in tree B in which maximum radial enlargement for any particular season occurred in 1942 during 21 weeks of activity with rainfall 101.95% of average, and the minimum radial enlargement occurred in 1944 during 24 weeks of activity with rainfall 95.28% of average. These data are tabulated in table II.

SUMMARY AND CONCLUSIONS

1. A dendrometer record of all weekly changes in radii of two trees of *Pinus strobus* is given for the five-year period, March 1, 1941 to March 30, 1946.

2. Time of initiation of true radial enlargement in the two trees, during this period, ranged from April 15 to May 26.

3. Temperature appears to be the most important limiting factor in controlling the time of initiation of radial enlargement. This varied from a few days before to as many days after the mean daily air temperature was continuously (or nearly so) above 50° F.

4. Initiation of radial enlargement followed closely the time of beginning of swelling of terminal buds.

5. The rate and amount of weekly radial change was irregular in both trees for all five of the growing seasons for which data are available.

6. Shrinkages due to dehydrations occurred during the normal enlarging season but at no time were they of more than two weeks duration. During the dormant season, shrinkages and recoveries were numerous and of varying extent and duration.

7. Average annual radial enlargement for the five-year period was 6.97 mm in tree A and 6.36 mm in tree B. It was concluded that these trees were in a vigorous growing condition.

8. Amounts of radial enlargement show a fair degree of correlation with percentages of average annual rainfall. The degree of correlation is greatest when rainfall change is from well below to average or above average.

9. Duration of radial enlargement varied, in the two trees and over the five-year period, from 17 to 28 weeks. It was concluded that *Pinus strobus* is a long-growing species.

10. Cessation of radial enlargement varied in time from the week ending September 18 to that ending November 1. There was no correlation between duration and amount of radial enlargement.

ACKNOWLEDGMENT

Sincere appreciation is here expressed to the United States Weather Bureau, New England Section, for making available the meteorological data used in this study.

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TABLE I

Radial behavior in two trees of *Pinus strobus,* Camden, Maine, March, 1941 to March, 1946. Times of initiation and cessation of true radial enlargement are enclosed in parentheses.

RADIAL CHANGES

Week Ending	Tree A Current Week	Tree A Total Change	Tree B Current Week	Tree B Total Change	Rainfall Inches Gardiner
3-30-41	0.40 mm	0.40 mm	0.52 mm	0.52 mm	0.66 in.
4- 5-41	0.44	0.84	0.24	0.76	0.03
4-12-41	0.24	1.08	0.04	0.80	0
4-19-41	0.16	1.24	0.04	0.84	0.20
4-26-41	0.28	(1.52)	0.20	1.04	0.21
5- 3-41	–0.08	1.44	0.08	(1.12)	0.25
5-10-41	0.28	1.72	0.36	1.48	0.16
5-17-41	0.28	2.00	0.44	1.92	0.18
5-24-41	0.40	2.40	0.16	2.08	0.55
5-31-41	0.28	2.68	0.20	2.28	1.05
6- 7-41	0.20	2.88	0.48	2.76	0
6-14-41	0.52	3.40	0.52	3.28	0.44
6-21-41	0.20	3.60	0.48	3.76	0.40
6-28-41	0.60	4.20	0.56	4.32	0.09
7- 5-41	0.36	4.56	0.36	4.68	0.19
7-12-41	0.40	4.96	0.60	5.28	1.39
7-19-41	0.44	5.40	0.44	5.72	0.81

TABLE I—(Continued)

Week Ending	Tree A		Tree B		Rainfall Inches Rockland
	Current Week	Total Change	Current Week	Total Change	
7-26-41	0.20	5.60	0.40	6.12	0.61
8- 2-41	0.60	6.20	0.48	6.60	0.46
8- 9-41	0.36	6.56	0.36	6.96	0.81
8-16-41	0.32	6.88	0.36	7.32	0.88
8-23-41	0.24	7.12	0.24	7.56	0.68
8-30-41	0.28	7.40	0.24	7.80	0.38
9- 6-41	0.12	7.52	0.12	7.92	0.66
9-13-41	0.16	7.68	0.08	8.00	0.16
9-20-41	–0.12	7.56	–0.06	7.94	0
9-27-41	–0.04	7.52	0.08	8.02	0
					Rockland
10- 4-41	0.32	7.84	0.12	8.14	1.75
10-11-41	0.04	7.88	0	8.14	0.63
10-18-41	0.04	7.92	0	8.14	0.21
10-25-41	0	7.92	0	8.14	0.17
11- 1-41	0.08	(8.00)	0.08	(8.22)	1.02
11- 8-41	–0.08	7.92	–0.12	8.10	4.63
11-15-41	–0.04	7.88	–0.08	8.02	0.21
11-22-41	0.04	7.92	0.04	8.06	0.08
11-29-41	0	7.92	0	8.06	0.47
12- 6-41	–0.04	7.88	0.08	8.14	0.56
12-13-41	0.08	7.96	–0.08	8.06	0.72
12-20-41	–0.84	7.12	–0.64	7.42	1.65
12-27-41	0.64	7.76	0.40	7.82	1.38
1- 3-42	–0.36	7.40	0.04	7.86	0.85
1-10-42	–1.00	6.40	–1.04	6.82	0.43
1-17-42	1.04	7.44	1.04	7.86	0.02
1-24-42	0.12	7.56	–0.44	7.42	2.27
1-31-42	0.20	7.76	0.20	7.62	0
2- 7-42	–0.12	7.64	0	7.62	1.49
2-14-42	–0.88	6.76	–0.76	6.85	0.53
2-21-42	–0.20	6.56	–0.04	6.81	1.11
2-28-42	0.40	6.96	0.28	7.19	0.03
3- 7-42	0.24	7.20	0.36	7.55	1.51
3-14-42	0.40	7.60	0.32	7.87	2.43
3-21-42	–0.08	7.52	–0.12	7.75	0.75
3-28-42	0.08	7.60	0.04	7.79	1.52
4- 4-42	0.12	7.72	0.04	7.83	1.18
4-11-42	0.20	7.92	0.12	7.95	0.95
4-18-42	0.08	8.00	0.04	7.99	0.82
4-25-42	–0.20	7.80	–0.20	7.79	1.24
5- 2-42	0.36	(8.16)	0.40	(8.19)	0.10
5- 9-42	0.24	8.40	0.36	8.55	0.74

TABLE I—(Continued)

Week Ending	Tree A		Tree B		Rainfall Inches Rockland
	Current Week	Total Change	Current Week	Total Change	
5-16-42	0.40	8.80	0.28	8.85	0.16
5-23-42	0.56	9.36	0.48	9.33	1.02
5-30-42	0.20	9.56	0.20	9.53	0.34
6- 6-42	0.64	10.20	0.40	9.93	0.53
6-13-42	0.60	10.80	0.48	10.41	0.19
6-20-42	0.28	11.08	0.20	10.61	3.91
6-27-42	0.36	11.44	0.40	11.01	0.29
7- 4-42	0.60	12.04	0.36	11.37	1.55
7-11-42	0.32	12.36	0.42	11.79	0.40
7-18-42	0.32	12.68	0.12	11.91	0.31
7-25-42	0.16	12.84	0.28	12.19	0.06
8- 1-42	0.36	13.20	0.44	12.63	1.30
8- 8-42	0.80	14.00	0.60	13.23	0.14
8-15-42	0.80	14.80	0.60	13.83	1.23
8-22-42	0.40	15.20	0.40	14.23	0.70
8-29-42	0.40	15.60	0.28	14.51	0.04
9- 5-42	0.20	15.80	0.32	14.83	0.22
9-12-42	0.28	16.08	0.16	14.99	0.89
9-19-42	0.64	16.72	0.52	(15.51)	0.54
9-26-42	0	16.72	0	15.51	0.69
10- 3-42	–0.12	16.60	–0.16	15.35	0.79
10-10-42	0.08	16.68	-0.04	15.31	0.90
10-17-42	0	16.68	0.08	15.39	0.01
10-24-42	0.04	16.72	0	15.39	1.93
10-31-42	0.08	(16.80)	0.04	15.43	0.20
11- 7-42	–0.20	16.60	–0.12	15.31	1.88
11-14-42	–0.08	16.52	–0.60	14.71	0.88
11-21-42	0.20	16.72	0.44	15.15	0.40
11-28-42	–0.32	16.40	–0.40	14.75	1.44
12- 5-42	0.40	16.80	0.44	15.19	2.59
12-12-42	–0.08	16.72	–0.08	15.11	0.01
12-19-42	–1.92	14.80	–0.80	14.31	0.12
12-26-42	0.72	15.52	–0.12	14.19	0.10
1- 2-43	–0.32	15.20	0	14.19	2.48
1- 9-43	–0.20	15.00	–0.08	14.11	0.19
1-16-43	0.52	15.52	0.04	14.15	0.36
1-23-43	–0.72	14.80	–0.60	13.55	0.71
1-30-43	0.24	15.04	0.28	13.83	0.30
2- 6-43	0.56	15.60	0.48	14.31	1.34
2-13-43	–0.28	15.32	–0.16	14.15	0.68
2-20-43	0.12	15.44	–0.20	13.95	0.81
2-27-43	–0.32	15.12	0	13.95	0.12
3- 6-43	0.48	15.60	0.40	14.35	0.34

TABLE I—(Continued)

Week Ending	Tree A		Tree B		Rainfall Inches Rockland
	Current Week	Total Change	Current Week	Total Change	
3-13-43	–0.36	15.24	–0.08	14.27	2.05
3-20-43	0.44	15.68	0.28	14.55	1.05
3-27-43	–0.32	15.36	–0.32	14.23	0.05
4- 3-43	0.76	16.12	0.72	14.95	0.14
4-10-43	–0.08	16.04	–0.08	14.87	0.12
4-17-43	0.36	16.40	0.36	15.23	1.07
4-24-43	–0.08	16.32	–0.20	15.20	0.95
5- 1-43	0.24	16.56	0.24	15.44	0.30
5- 8-43	0	16.56	0	15.44	2.10
5-15-43	0.12	16.68	0.28	(15.72)	1.77
5-22-43	0.32	(17.00)	0.42	16.14	0.79
5-29-43	0.42	17.42	0.40	16.54	0.92
6- 5-43	0.40	17.82	0.44	16.98	0.93
6-12-43	0.60	18.42	0.52	17.50	0.36
6-19-43	0.36	18.78	0.36	17.86	0.37
6-26-43	0.28	19.06	0.44	18.30	0.18
7- 3-43	0.32	19.38	0.12	18.42	1.01
7-10-43	0.36	19.74	0.36	18.78	0.75
7-17-43	0.28	20.02	0.16	18.94	0
7-24-43	0.36	20.38	0.40	19.34	2.51
7-31-43	0.52	20.90	0.36	19.70	3.71
8- 7-43	0.24	21.14	0.16	19.86	3.02
8-14-43	0.56	21.70	0.56	20.42	1.72
8-21-43	0.08	21.78	0.20	20.62	0.29
8-28-43	0.48	22.26	0.28	20.90	0.13
9- 4-43	0.08	22.34	0.84	21.74	0.15
9-11-43	0.76	23.10	–0.40	21.34	0.16
9-18-43	0.24	23.34	0.44	(21.78)	1.44
9-25-43	0.24	23.58	–0.36	21.42	0.88
10- 2-43	0.32	23.90	0.16	21.58	0
10- 9-43	–0.24	23.66	–0.24	21.34	2.89
10-16-43	0.32	(23.98)	0.04	21.38	2.37
10-23-43	–0.20	23.78	–0.08	21.30	3.13
10-30-43	–0.28	23.50	–0.16	21.14	1.46
11- 6-43	0.08	23.58	0.04	21.18	1.12
11-13-43	0.04	23.62	0.04	21.22	1.39
11-20-43	0.04	23.66	0	21.22	0.25
11-27-43	–0.04	23.62	–0.12	21.10	2.74
12- 4-43	0.04	23.66	0.24	21.34	0
12-11-43	–0.16	23.50	–0.36	20.98	1.17
12-18-43	–0.20	23.30	0	20.98	0.19
12-25-43	0.08	23.38	0	20.98	0
1- 1-44	–0.08	23.30	–0.08	20.90	0.25

TABLE I—(Continued)

Week Ending	Tree A		Tree B		Rainfall Inches Rockland
	Current Week	Total Change	Current Week	Total Change	
1- 8-44	0.04	23.34	–0.08	20.82	1.28
1-15-44	0.24	23.58	0	20.82	0
1-22-44	–0.28	23.30	–0.08	20.74	0
1-29-44	0.40	23.70	–0.24	20.50	0.42
2- 5-44	–0.52	23.18	–0.20	20.30	0.16
2-12-44	–0.08	23.10	–0.16	20.14	0.93
2-19-44	–0.48	22.62	–0.08	20.06	1.50
2-26-44	0.78	23.40	0.16	20.22	1.37
3- 4-44	–0.80	22.60	–0.20	20.02	0
3-11-44	0.40	23.00	0.48	20.50	1.68
3-18-44	–0.16	22.84	–0.20	20.30	1.18
3-25-44	0	22.84	0.08	20.38	1.07
4- 1-44	0.72	23.56	0.92	21.30	1.26
4- 8-44	0.40	23.96	0.28	21.58	0.14
4-15-44	0.24	(24.20)	0.04	21.62	1.67
4-22-44	–0.08	24.12	0.12	21.74	0.59
4-29-44	0.16	24.28	0.12	(21.86)	1.18
5- 6-44	0.20	24.48	0.28	22.14	0
5-13-44	0.12	24.60	0.04	22.18	0.26
5-20-44	0.32	24.92	0.44	22.62	0.37
5-27-44	0.56	25.48	0.64	23.26	0.25
6- 3-44	0.56	26.04	0.72	23.98	0.04
6-10-44	0.56	26.60	0.48	24.46	0.26
6-17-44	0.08	26.68	0.20	24.66	0.97
6-24-44	0.56	27.24	0.44	25.10	1.51
7- 1-44	–0.04	27.20	–0.08	25.02	1.13
7- 8-44	0.40	27.50	0.16	25.18	0.06
7-15-44	0.28	27.88	0.40	25.58	0.07
7-22-44	0.24	28.12	0.04	25.62	0.19
7-29-44	0.48	28.60	0.52	26.14	2.06
8- 5-44	–0.32	28.28	0.16	26.30	0.34
8-12-44	0.40	28.68	–0.36	25.94	0
8-19-44	0	28.68	0.12	26.06	0.16
8-26-44	0.12	28.80	0.04	26.10	0.45
9- 2-44	0.44	29.24	0.28	26.38	0.03
9- 9-44	–0.12	29.12	–0.16	26.22	0.98
9-16-44	0.44	29.56	0.40	26.62	4.70
9-23-44	0.04	29.60	–0.08	26.54	0.12
9-30-44	0.12	29.72	0	26.54	1.48
10- 7-44	0.16	(29.88)	0.24	(26.78)	0.38
10-14-44	–0.12	29.76	–0.12	26.66	0.64
10-21-44	–0.08	29.68	–0.08	26.58	1.44
10-28-44	–0.08	29.60	–0.04	26.54	0.13

TABLE I—(Continued)

Week Ending	Tree A		Tree B		Rainfall Inches Rockland
	Current Week	Total Change	Current Week	Total Change	
11- 4-44	0.16	29.76	0.12	26.66	0
11-11-44	0	29.76	0	26.66	3.08
11-18-44	–0.08	29.68	–0.12	26.54	0
11-25-44	–0.04	29.64	–0.04	26.50	0.74
12- 2-44	–0.32	29.32	–0.28	26.22	2.98
12- 9-44	0.08	29.40	0.32	26.34	0.70
12-16-44	–0.56	28.84	–0.04	26.30	0.91
12-23-44	–0.36	28.48	–0.72	25.58	0.03
12-30-44	–0.76	27.72	–0.24	25.34	1.99
1- 6-45	0.40	28.12	0.12	25.46	1.80
1-13-45	–0.36	27.76	–0.04	25.42	0.92
1-20-45	–0.04	27.72	–0.08	25.34	0.98
1-27-45	0.12	27.84	0	25.34	0.18
2- 3-45	0.08	27.92	–0.04	25.30	0.92
2-10-45	0.28	28.20	0.44	25.74	1.24
2-17-45	–0.52	27.68	–0.36	25.38	0.56
2-24-45	0.12	27.80	0	25.38	1.19
3- 3-45	–0.32	27.48	–0.04	25.42	0.88
3-10-45	0.52	28.00	0.20	25.62	0.60
3-17-45	0.32	28.32	0.16	25.78	0.44
3-24-45	0.36	28.68	0.68	26.46	1.04
3-31-45	–0.08	28.60	–0.24	26.22	0.03
4- 7-45	0.16	28.76	–0.04	26.18	2.16
4-14-45	0	28.76	0.20	26.38	0
4-21-45	–0.12	28.64	–0.20	26.18	0.41
4-28-45	0.56	29.20	0.52	26.70	2.02
5- 5-45	0.28	29.48	0.32	(27.02)	1.78
5-12-45	–0.04	29.44	–0.04	26.98	2.59
5-19-45	0.24	29.68	0.16	27.14	2.35
5-26-45	0.24	(29.92)	0.32	27.46	0.04
6- 2-45	0.28	30.20	0.24	27.70	1.46
6- 9-45	0.36	30.56	0.36	28.06	0.30
6-16-45	0.52	31.08	0.64	28.70	2.32
6-23-45	0.36	31.44	0.36	29.06	1.93
6-30-45	0.60	32.04	0.40	29.46	0.77
7- 7-45	0.20	32.24	0.28	29.74	0.20
7-14-45	0.36	32.60	0.36	30.10	0.43
7-21-45	0.40	33.00	0.44	30.54	0.57
7-28-45	0.48	33.48	0.44	30.98	0.16
8- 4-45	0.08	33.56	0.24	31.22	0.94
8-11-45	0.48	34.04	0.28	31.50	0.17
8-18-45	0.44	34.48	0.48	31.98	0.01
8-25-45	0.44	34.92	0.36	32.34	0.49

TABLE I—(Continued)

Week Ending	Tree A Current Week	Tree A Total Change	Tree B Current Week	Tree B Total Change	Rainfall Inches Rockland
9- 1-45	0.36	35.28	0.40	32.74	1.76
9- 8-45	–0.04	35.24	–0.28	32.46	0.33
9-15-45	0.56	35.80	0.48	32.94	0.67
9-22-45	0.04	35.84	–0.24	32.70	1.44
9-29-45	0.28	36.12	0.16	32.86	0.31
10- 6-45	0.20	(36.32)	0.20	(33.06)	1.37
10-13-45	–0.08	36.24	–0.04	33.02	1.64
10-20-45	–0.16	36.08	–0.28	32.74	0.09
10-27-45	–0.08	36.00	0	32.74	0.92
11- 3-45	0.04	36.04	0.24	32.98	0.04
11-10-45	–0.16	35.88	–0.32	32.66	0.81
11-17-45	0.08	35.96	0.12	32.78	0.63
11-24-45	0	35.96	–0.12	32.66	3.39
12- 1-45	0	35.96	0	32 66	0.70
12- 8-45	0.16	35.80	0.12	32.78	1.91
12-15-45	–1.00	34.80	–0.72	32.06	0
12-22-45	–0.12	34.68	–0.08	31.98	0.24
12-29-45	0.80	35.48	0.28	32.26	1.45
1- 5-46	0.08	35.56	0.12	32.38	
1-12-46	–0.04	35.52	0	32.38	
1-19-46	–1.24	34.28	–0.84	31.54	
1-26-46	0.44	34.72	0.36	31.80	
2- 3-46	0.08	34.80	–0.16	31.64	
2- 9-46	–0.04	34.76	0.04	31.68	
2-16-46	–0.32	34.44	–0.24	31.44	
3- 2-46	0.44	34.88	0.32	31.76	
3- 9-46	0.20	35.08	0.20	31.96	
3-16-46	0.16	35.24	0.32	32.28	
3-23-46	0.24	35.48	0.16	32.44	
3-30-46	0.28	35.76	0.12	32.56	

TABLE II

Summarized enlargement data, *Pinus strobus*. Enlargement is given in terms of mm of radial change, 1941-1945.

Year	Initiation of Radial Change		Cessation of Radial Change		Weeks of Enlargement		Amount of Radial Enlargement in mm		Days Mean Daily Temperature 50° F. Before Initiation of Enlargement		Percentage Average Annual Rainfall	Number Clear Days
	A	B	A	B	A	B	A	B	A	B		
1941	4-26	5- 3	11- 1	11- 1	28	27	6.56	6.98	6-13	13-20	70.05	
1942	5- 2	5- 2	10-31	9-19	27	21	8.80	7.29	4-11	4-11	101.95	161
1943	5-22	5-15	10-16	9-18	22	19	7.18	6.27	1- 8	8-15	114.56	177
1944	4-15	4-29	10- 7	10- 7	26	24	5.90	5.00	–(14-21)	–(1- 8)	95.28	202
1945	5-26	5- 5	10- 6	10- 6	20	23	6.44	6.28	7-14	–(7-14)	103.96	172
Total							34.88	31.82				

TABLE III

Maximum, minimum, and mean daily temperatures, Winslow and Rockland, Maine, for April and May, 1941-1945.

	1941			1942			1943			1944			1945		
	Winslow			Rockland			Rockland			Rockland			Rockland		
Date	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
April															
1	53	40	27	43	38.5	34	39	33	27	47	36	25	66	52.5	39
2	53	40.5	28	55	42	29	38	32	26	58	43.5	29	62	49	36
3	57	44.5	32	57	46	35	38	31	24	45	34	23	59	46	33
4	56	44	32	51	37	23	43	30.5	18	45	33	21	40	33.5	27
5	57	45.5	24	41	37	33	49	33.5	18	43	34	25	50	41	32
6	54	43.5	33	55	42	29	41	29	17	48	36.5	25	45	35.5	26
7	54	40.5	27	56	45.5	35	43	28.5	14	51	41	31	50	34.5	19
8	58	47	36	52	42	32	43	33	21	43	32.5	22	59	37.5	36
9	63	45.5	28	49	39.5	30	54	39.5	25	54	41	28	67	50.5	34
10	64	48.5	33	42	37	32	49	35.5	22	43	38	33	64	51	38
11	64	52	40	45	37	29	46	36.5	27	50	39	28	72	56	40
12	67	48	29	42	36	30	46	34	22	41	36.5	32	71	54.5	38
13	67	49.5	32	53	40	27	55	38	21	47	40	33	59	49.5	40
14	72	57.5	43	53	40	27	48	41.5	35	43	34.5	26	73	55.5	38
15	72	57.5	43	49	38	27	41	31.5	22	44	35.5	27	59	43	27
16	70	60.5	51	58	36.5	35	43	30.5	18	43	37.5	32	52	37	22
17	69	51.5	34	52	40	28	48	39.5	31	41	37.5	34	52	45	38
18	68	56	44	48	42.5	37	55	41	27	57	43.5	30	67	57.5	46
19	68	56.5	45	42	37	32	53	41	29	59	43.5	28	55	43	31
20	80	61	42	42	38.5	35	43	37	31	56	45.5	34	58	42	26
21	82	67	52	45	40.5	36	44	38	32	48	37	26	59	49.5	40
22	70	54.5	39	64	50.5	37	57	45	33	54	39	24	45	39	33
23	57	42	27	68	50.5	33	68	47.5	27	56	41	26	50	37.5	25
24	56	48.5	41	75	56	37	67	47.5	28	45	39	33	60	43.5	27
25	50	45.5	41	79	59.5	40	64	48.5	33	54	44.5	35	49	40.5	32
26	62	46.5	31	68	56.5	45	62	51	40	52	43	34	45	40.5	36
27	59	49.5	40	52	44	36	54	40.5	27	52	41.5	29	44	41	38
28	75	60.5	46	54	40.5	27	59	46	33	53	42.5	32	49	42.5	36
29	75	56.5	38	62	50.5	39	56	42	28	62	45	28	54	46	38
30	65	55	45	80	61.5	43	50	37.5	25	73	54	36	53	43.5	34
May															
1	60	50	40	74	59	44	48	40	32	65	53	41	55	46.5	38
2	56	46.5	37	62	49	36	59	40.5	22	57	43	29	52	42	32
3	61	48	35	63	53.5	44	49	41.5	34	60	46	32	52	39.5	37
4	64	48	32	72	59	47	53	45.5	38	62	52	42	43	40	37
5	70	57.5	45	66	54	42	62	48	34	65	54	43	59	44	39
6	78	55.5	33	65	53.5	42	63	48.5	34	50	47	44	57	47.5	38
7	82	65.5	49	51	46.5	42	58	48.5	39	51	47	43	65	49	33
8	74	64	54	53	47	41	70	56.5	43	72	58.5	45	58	45	32

TABLE III—(Continued)

Date	1941 Winslow Max.	 Mean	 Min.	1942 Rockland Max.	 Mean	 Min.	1943 Rockland Max.	 Mean	 Min.	1944 Rockland Max.	 Mean	 Min.	1945 Rockland Max.	 Mean	 Min.
May															
9	80	65	50	61	47	33	72	58	44	64	50.5	37	60	47	34
10	77	65.5	54	53	46.5	40	63	51.5	40	60	51.5	43	55	43	31
11	73	53.5	42	67	50.5	34	60	51.5	43	67	55	43	45	37.5	30
12	68	51	34	69	52	35	50	45	40	77	60.5	44	59	43.5	28
13	64	52	40	58	51	44	62	52.5	43	60	53	46	60	50.5	41
14	69	51	33	51	47.5	44	61	50.5	40	74	60	46	68	55.5	43
15	74	61	48	62	52	42	65	51	37	65	52	39	67	56	45
16	84	62.5	43	51	47	43	57	43.5	30	65	51.5	38	62	53	44
17	85	67	49	69	58.5	48	69	56.5	44	75	58.5	42	54	48.5	43
18	80	62.5	45	69	59	49	79	67	55	60	53	46	58	50.5	43
19	78	63	36	68	57.5	47	66	58	50	63	46.5	30	54	47	40
20	77	59	41	62	55.5	49	60	52.5	45	69	50	31	66	52	38
21	81	63	45	64	57.5	51	52	43.5	35	73	55	37	57	45	33
22	90	70.5	51	59	54	49	59	50	41	56	50	44	55	48	41
23	89	70.5	52	55	52.5	50	61	50	39	59	52.5	46	69	56.5	44
24	72	66	60	56	52.5	49	80	60	40	73	55.5	38	64	52	40
25	69	56.5	44	73	57.5	42	70	57.5	45	73	57.5	42	66	49.5	33
26	68	58	48	62	53	44	55	50	45	70	58.5	47	64	50.5	37
27	67	59	51	67	54.5	42	73	59	45	76	53.5	51	64	49.5	35
28	61	53	45	67	56	42	76	63	50	85	68.5	52	59	50.5	42
29	65	56.5	48	76	57.5	39	66	55.5	45	79	65.5	52	74	59.5	45
30	67	53.5	40	84	69	54	64	54	44	77	59	41	58	49	40
31	76	57.5	39	76	62	48	67	51.5	36	92	61.5	51	57	47.5	38

TABLE IV

Rainfall, Rockland: Monthly and annual in inches and percentage of six-year average. Clear, cloudy, and partly cloudy days.

		1940	1941	1942	1943	1944	1945	6-year Av. Inches
January	R	2.12	2.59	3.77	1.67	1.70	4.74	2.76
	% Av.	76.9	94.0	136.5	60.5	61.6	170.0	
February	R	3.37	1.82	3.20	2.85	3.96	3.87	3.18
	% Av.	105.9	56.2	100.5	89.8	124.4	121.6	
March	R	3.70	4.21	6.92	3.56	5.18	2.13	4.28
	% Av.	86.5	98.7	161.4	83.3	120.6	49.5	
April	R	8.03	1.17	3.58	3.20	3.58	4.65	4.03
	% Av.	199.2	29.0	89.0	79.5	89.0	115.8	
May	R	3.77	2.28	2.26	5.64	0.89	8.16	3.83
	% Av.	98.5	59.5	59.1	143.2	23.2	213.0	
June	R	3.90	0.82	5.92	2.09	3.91	5.82	3.74
	% Av.	104.2	21.9	158.0	56.0	104.5	155.5	
July	R	3.44	1.88	3.62	6.97	2.50	2.18	3.43
	% Av.	100.0	54.9	105.3	203.0	73.0	63.6	
August	R	1.56	2.76	2.11	5.15	0.83	1.65	2.34
	% Av.	66.7	117.9	90.4	220.0	35.4	70.6	
September	R	6.45	0.67	3.12	2.62	7.31	3.65	3.97
	% Av.	159.6	16.8	78.5	66.0	184.1	92.1	
October	R	0.67	4.27	3.04	9.86	2.59	4.03	4.02
	% Av.	16.6	106.2	75.7	244.0	64.6	100.2	
November	R	6.76	5.57	4.91	6.50	6.82	5.56	6.18
	% Av.	109.0	90.2	79.6	105.0	110.2	90.1	
December	R	3.83	3.59	3.56	1.61	3.69	4.05	3.39
	% Av.	112.9	105.9	105.0	47.5	108.7	119.2	
Total	R	37.60	31.63	46.01	51.72	42.97	46.49	45.15
	% Av.	105.5	70.1	101.9	114.6	95.3	104.0	
May-Aug.	R	12.67	7.74	13.91	19.85	8.13	17.81	12.94
	% Av.	97.7	59.6	107.4	153.0	62.7	137.5	
Radial Enlargement	A		6.56 mm	8.80	7.18	5.90	6.44	
	B		6.98	7.29	6.27	5.00	6.28	
Clear Days				161	177	202	172	
Partly Cloudy Days				87	82	73	73	
Cloudy Days				117	106	91	120	

TABLE V

Maximum, minimum, and mean daily temperatures, Winslow and Rockland, Maine, for September and October, 1941-1945.

Date	1941 Winslow			1942 Rockland			1943 Rockland			1944 Rockland			1945 Rockland		
	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
September															
1	66	60	54	90	70	50	75	61.5	48	69	59.5	48	64	58.5	53
2	72	66	60	87	70	53	64	56	48	79	68	57	73	65	57
3	80	61.5	43	74	65	56	71	61.5	52	82	68	54	71	59	47
4	81	66	51	66	60	54	65	59	53	80	65	50	70	54	38
5	80	68	56	77	64	51	70	62	54	66	59	52	84	62.5	41
6	71	63	55	69	53	37	64	59	54	71	63.5	56	82	65.5	49
7	83	68.5	54	72	55.5	39	70	62.5	55	70	62	54	94	74.5	55
8	78	64	50	74	64	54	73	64.5	56	71	55	39	95	77	59
9	67	57.5	46	62	56.5	51	80	65.5	51	74	58.5	43	77	65.5	54
10	67	59.5	52	61	55.5	50	75	64	53	74	58	42	70	61.5	53
11	70	64	58	69	61.5	54	71	56.5	42	74	57.5	41	75	65	55
12	68	53.5	39	69	60	51	69	54.5	40	74	59	44	78	68.5	57
13	63	51	39	78	67	56	70	54.5	39	63	58	53	78	63.5	49
14	76	60.5	45	74	60	46	72	54	36	72	64	56	66	54	42
15	84	72	60	71	59	47	59	54	49	84	71	58	72	63	54
16	88	78	68	73	64	55	78	60.5	43	79	69	59	65	57	49
17	84	69	54	79	66.5	54	66	55	44	68	59	50	61	48.5	36
18	84	67.5	51	72	63	54	62	51	40	67	55.5	44	62	50	38
19	72	56	40	66	60	54	62	45.5	29	69	50.5	52	69	58	47
20	69	52	35	68	61	54	76	56.5	37	71	62	53	63	54	45
21	81	64	47	57	51.5	46	76	59	42	72	62.5	53	79	65	51
22	87	66	45	59	52	45	61	54.5	48	68	60.5	53	68	55	42
23	89	70	51	69	53	37	66	58.5	51	60	48.5	37	65	49	33
24	78	61	44	65	51	37	65	55.5	46	61	45.5	30	61	49.5	38
25	70	57	44	63	55	47	65	54.5	44	62	46.5	31	82	68	54
26				65	50.5	36	64	52.5	41	66	50.5	35	78	68	58
27	71	53	35	67	58	49	65	47.5	30	62	52	42	71	57	43
28	74	54.5	35	65	58.5	52	72	56	40	59	54	49	60	54	48
29	74	59	44	55	42.5	30	62	51.5	41	63	54	45	74	58	42
30	60	44.5	27	59	43.5	28	59	50	41	66	51.5	37	55	45	35
October—Rockland															
1	75	60	45	59	50	41	59	52.5	46	56	47	38	51	40.5	30
2	68	51	34	60	47	34	63	57	51	65	52	39	65	55	45
3	58	48	38	64	51	38	65	56.5	48	52	42	32	58	46.5	35
4	79	64.5	50	63	57.5	32	57	48.5	40	63	46	29	55	40.5	26
5	69	55	41	66	53	40	53	45.5	38	67	49.5	32	61	49	37
6	67	54	41	67	60.5	54	65	47.5	30	59	48.5	38	62	53.5	45
7	56	51.5	47	63	49.5	36	68	54.5	41	79	56.5	54	59	56	53

TABLE V—(Continued)

Date	1941 Rockland			1942 Rockland			1943 Rockland			1944 Rockland			1945 Rockland		
	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
October															
8	71	59.5	48	69	51.5	34	67	48.5	30	63	57	51	69	62	55
9	62	51	40	71	59	47	78	59	40	56	52	48	62	52.5	43
10	53	45	37	66	55	44	67	47.5	28	59	52.5	46	59	44.5	30
11	53	45	37	66	49.5	33	59	40.5	22	60	53	46	55	43.5	32
12	49	41	33	61	51	41	68	48	28	69	55	41	51	41	31
13	60	47.5	35	65	47	29	70	52.5	35	57	52.5	48	57	47.5	38
14	55	43.5	32	64	48	32	65	49.5	34	58	52	46	57	45.5	34
15	70	55.5	41	65	54.5	44	64	56.5	49	54	45	36	57	45.5	34
16	55	45	35	59	48	37	61	55.5	50	53	39	25	51	42	33
17	57	43	29	60	44	28	64	56.5	49	60	45.5	31	58	46	34
18	59	44	29	47	39.5	32	57	44	31	70	52.5	35	59	45.5	32
19	58	48.5	39	59	46	33	51	44.5	38	63	50.5	38	54	47	40
20	65	47.5	30	56	42.5	29	49	42	35	57	41	25	71	56	41
21	67	49.5	32	60	44	28	50	44.5	39	48	43	38	64	49	34
22	65	53.5	42	59	53	47	53	42.5	32	49	40.5	32	60	48	36
23	55	43	31	65	58	51	50	44	38	60	42.5	25	57	52	47
24	55	44	33	58	50.5	43	45	39	33	58	44.5	31	48	42.5	37
25	47	36	25	55	47	39	49	41	33	60	52	44	49	43.5	38
26	43	31	19	53	49.5	46	53	44	35	58	53	48	50	45	40
27	59	44.5	30	56	44.5	33	50	45	40	54	45.5	37	51	43	35
28	59	51	43	53	41	29	55	50	45	43	38	33	42	37.5	33
29	48	36	24	56	40.5	25	60	52	44	45	38	31	49	35	21
30	43	34	25	59	53.5	48	58	48.5	39	43	34.5	26	58	47	36
31	50	42.5	35	56	51.5	47	52	41	30	46	31	16	59	46	33

THE CABIN CREEK RAISED BOG, RANDOLPH COUNTY, INDIANA

By Ray C. Friesner and J. E. Potzger

INTRODUCTION

High moors, or raised bogs, are a rather common physiographic feature of northern Europe, but in North America they are more or less limited to coastal areas. Some of these American raised bogs are described by Ganong (5) for New Brunswick, by Nichols (10) and Dachnowski (2) for Maine, and by Rigg (11) for southeastern Alaska. In more recent years a few raised bogs have also been reported for inland areas in North America. Gordon (7) described one at Urbana, Ohio, and Rigg (11, 12) one at Itaska Park, Minnesota, and another at Yellowstone Park.

All authors who described raised bogs stressed their infrequent occurrence, especially in interior locations. It was, therefore, more than the first thrill of contact with a raised bog which enthused the authors about discovery of a raised bog in centrally located Indiana. Naturally, a detailed study was planned at once. We called it Cabin Creek Raised Bog because of its location in the floodplain of Cabin Creek. The peat mass is a prominent feature of the landscape; it rises 10 feet above the floodplain at the maximum elevation. The answer to the question of its origin, nature of the peat, history of the development, and configuration of the topography now covered by the peat was sought in numerous borings and in pollen profile studies.

Cabin Creek Bog is located about 500 feet south of Cabin Creek, 6 miles north of Modoc, Randolph County, Indiana, along Highway 1. The whole region is glaciated terrain, dating to activity of Early Wisconsin glaciation. It is approximately 50 miles south of the limits of Late Wisconsin glaciation in Indiana. The topography is rolling, and at some places marked by numerous granitic erratics. A number of smaller bogs and a completely filled-in extinct lake (filled to a depth of 34 feet) on the farm of Mr. Reed are only a short distance south of the Cabin Creek Bog.

SURVEY OF REPORTS ON SOME RAISED BOGS

From the description of raised bogs in Europe it appears that some raised bogs of North America differ from those of Europe both as to initial origin and factors involved in the formation. Brehm (1) says that high moors of northern Europe are frequent along borders of lakes, or they may occur where lakes have completely filled in, rising above the level of the old shore line. He says that the name originated from the fact that the peat forms convex elevations in the central portion to rise above the perimeter. He describes the contour as being like a watch crystal. The central portion may at times be several meters higher than the rim. Intensive growth of Sphagnum is given as cause of such peat accumulations. Heil (8) states that high moors may occur in lowland areas as well as on upper slopes of mountains. These moors are surrounded by a moat into which excess water from the elevated mass flows. Thienemann (13), as well as Lenz (9), stresses the fact that high moors of Europe are formed under conditions of calcium deficiency and high acidity.

In North America raised bogs are chiefly along coastal areas of Maine, New Brunswick, and southeastern Alaska. In Maine they seem to be limited to a belt not over 30 miles inland from the coast. Dachnowski-Stokes (3) classifies the eastern bogs of this type under the heading of "Champlain series of peat profiles." He says, "The raised dome-shaped surface is due to an upward growth and periodic accumulation of Sphagnum mosses . . . . the groundwaters are generally soft and otherwise low in mineral salts."

Bogs of the Champlain series are, thus, very similar to the high moors of Europe. However, many of the raised bogs of our eastern coastline owe their initial development, perhaps also their very existence, to artesian springs, as Ganong (5) has pointed out for the bogs of New Brunswick.

Riggs (11) describes in detail the raised bogs of southeastern Alaska. While they, too, are similar to the European bogs in that Sphagnum is the cause of their formation, he finds that some are apparently caused by artesian springs. Water flows from some of them. The same author also attributes formation of the young raised bog in Yellowstone Park to artesian springs.

For eastern inland areas Gordon (7) described a raised bog at Urbana, Ohio. This particular bog has some features in common with the Cabin Creek Bog. Chief of such similarities are high alkalinity of the water, origin from artesian springs, dense mats of Chara in the small streams flowing from the peat mass, elevation of the mass by 10 to 13 feet, absence of Sphagnum and ericads, prairie grasses as an important element associated with typical bog plants. The Indiana bog, however, differs from the Ohio bog in that the hydrostatic pressure has not elevated the peat mat, leaving open water beneath.

Considering the various reports on raised bogs, we may be justified to say that three types of raised bogs are found in America, viz., (1) raised Sphagnum bogs similar to those of Europe, as reported by Nichols (10) for Maine, and by Rigg (11) for southeastern Alaska; (2) raised bogs due to artesian springs and Sphagnum as chief contributor to the peat formed (Ganong, 3); and (3) raised bogs due to artesian spring water, high in calcium, with mosses, sedges, and grasses as chief peat formers. This latter type is found in inland areas, and it presents two variants. The one variant has vegetation encroaching on springs, finally to be lifted up by the hydrostatic pressure; the other variant has weakly expressed hydrostatic pressure which gives rise to wet areas favorable to luxuriant growth of mosses (Drepanocladus) as well as growth of sedges and grasses. The accumulating remains will form an ever-deepening layer of peat, this by uniform deposition will gradually build up a convex mound. Of the former type Gordon (7) reports a striking example at Urbana, Ohio, and the Cabin Creek Bog is an excellent example of the latter type.

METHODS OF STUDY

The present vegetation of the peat mass was studied intensively at all seasons over a period of two years. The original surface configuration of the land now covered with peat was determined by means of borings at 50-foot intervals along eight radii which all passed through the centrally located deepest place (boring 7). The floodplain of Cabin Creek served as base line for determination of elevations by aid of a hand level. Peat samples for complete pollen profile studies at one-foot intervals were taken at five borings, viz., borings 4, 5, 6, and 7. Customary procedures for securing samples for pollen analysis with a Hiller-type borer were followed. Preparation of slides for pollen count was according to the Geisler (5) method. The maximum count for any one foot-level was 100 pollen grains, and at levels where pollen representation was very sparse, pollens present on five microscope slides were counted and tabulated. For boring 4 only the bottom two foot-levels were studied to determine the time when depositions began. Since borings 5 and 6 were located similarly to boring 1, no pollen study was made of these peat samples.

Sediments were examined for marl with HCl reaction, and some concept on amount of marl present was formed on degree of violence of effervescence which resulted. An arbitrary scale of 4 was used to express these differences. Every sample was then examined microscopically to determine the source of the organic matter contained (table I).

CAUSES UNDERLYING FORMATION OF THE BOG

As stated previously, the Cabin Creek Bog is similar to the one at Urbana, Ohio, as well as to some of the eastern bogs of New Brunswick, and to the one at Yellowstone in that springs provided the necessary moisture for peat accumulation. To the south, Cabin Creek Bog borders on a higher morainal mass from which water must have flowed under considerable hydrostatic pressure. This finds expression in several streams which today flow from the topmost levels of the peat to nearby Cabin Creek. In no case did we find open water beneath the peat, but rather a fairly compacted mass of peat through which water was forced by some head pressure. The deep hole (boring 7) was perhaps initially water-filled, and so the early filling was due to water-deposited, finely divided material, composed mainly of inorganic particles and marl, but small pieces of wood, a few leaves of mosses and parts of sedges also appear. This type of deposition operated to the 13-foot level. From the 12-foot to the 8-foot level mosses and sedges contributed the organic sediment constituents. From the 7-foot to the 1-foot levels peat was formed chiefly by wood, and marl was absent. In all of these but the 4-foot level HCl gave no reaction (table I). Three types of sediments, thus, played a part in the total accumulation of the fill, viz., those which settled out in water, remains of marsh plants, and woody material contributed by shrubs and trees. The speed of accumulation no doubt varied, too. The bottom 28 foot-levels (deposited during the Picea period) represent, perhaps, a smaller time interval than the top-most three levels, which have accumulated since the close of the Picea period.

Accumulation at boring 1 was all on land. In general there is a correlation between deposits here and those at boring 7 at the close of deposition in water (12-foot level) except that wood played a minor role in formation of peat at boring 1, while mosses were more important. At boring 1 only the 7-foot level shows the unusual absence of marl while at boring 7 sediments from levels 7 to 1 gave no marl reaction with HC1. Why woody peat at the 7-foot level should be followed by sedge peat is difficult to explain. It may indicate a dry period during which shrubs and trees invaded the peat mass. In a general way, there is some similarity in the process of sedimentation between levels 7 to 1 in boring 1 and levels 12 to 1 in boring 7, but pollen records in the two profiles do not correlate at these horizons. In boring 7 Picea still shows great importance at the 4-foot level while at boring 1 pine-oak has already replaced spruce at the 6-foot level.

HISTORY OF THE VEGETATION BASED ON POLLEN PROFILES

The Cabin Creek Bog differs from all raised bogs studied to date by the complex topographic configuration over which it has spread, i. e., a very deep depression (boring 7) with extremely steep sandy slopes (boring 1). Naturally one would, therefore, also expect differences in the manner in which organic matter accumulated to form the present-day mass. The deep depression has to the 28-foot level an accumulation of pitch-black, finely divided material which for the greater part consisted of inorganic particles and marl, but some small fragments of wood, sedges and mosses were found. Water deposition is evident to the 12-foot level, when the marl-inorganic material was replaced by moss-sedge peat (table I). Wood replaced mosses and sedges as source of the peat at the 7-foot level, and continued to the topmost level.

On top of the sandy slope (boring 1) the sandy soil is abruptly overlain by three feet of a coarse, raw Drepanocladus* peat. This is succeeded by 3 feet of sedge-moss peat, one foot of wood peat, 4 feet of sedge peat, and all is topped off by 2 feet of sedge-wood peat. Marl played an important role in the total deposit except at the 7-foot level where a dark-brown wood-sedge peat gave no reaction with HC1.

* We are indebted to Dr. William C. Steere for determination of the moss.

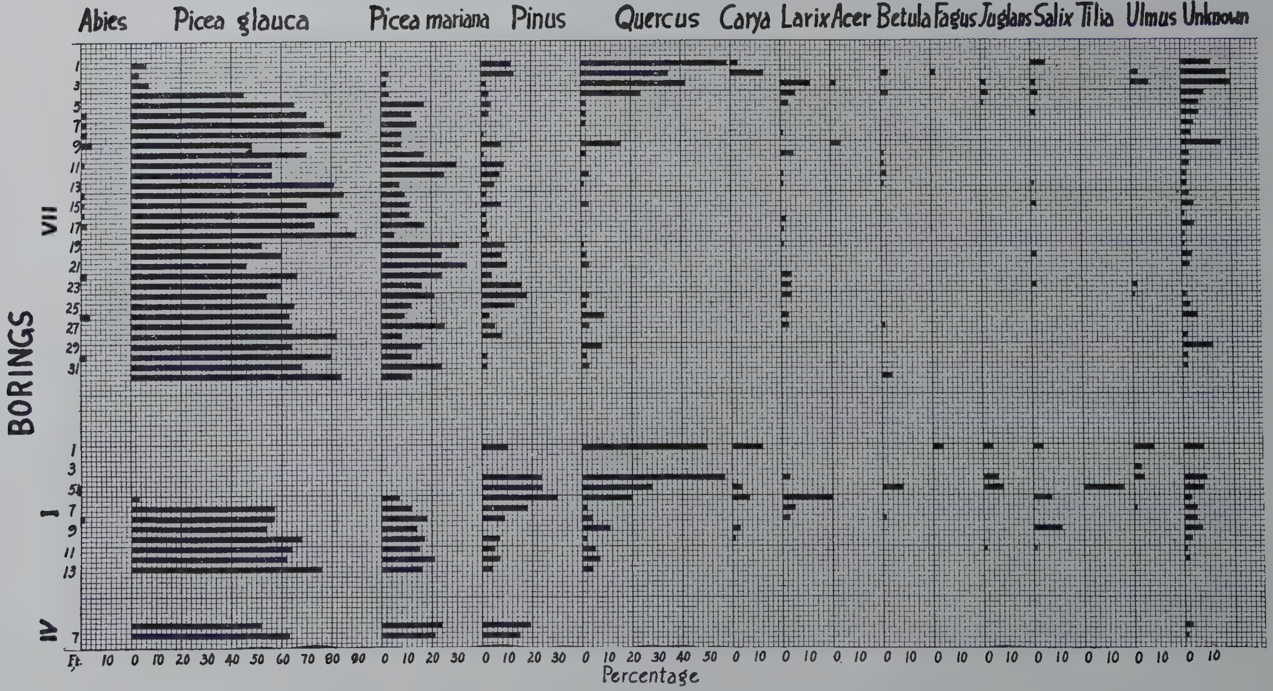

Fig. 1. Pollen.ropfile, Cabin Creek Bog.

In lower levels pollen was quite abundant, and was excellently preserved, but in the topmost levels pollen representation was very sparse. The writers have never before encountered so many foot-levels where Picea controlled as at boring 7. With some fluctuations between *Picea mariana* and *P. glauca,* spruce contributed the major pollen accumulation throughout 28 foot-levels, which at the 4-foot level began to give way rather suddenly to Quercus (fig. 1). While Quercus has higher representation in topmost levels than any one other genus, a mixed mesophytic forest is indicated by the large number of broad-leaved genera which enter the profile (fig. 1). In the profile from the ridge location (boring 1) Picea indicated dominance during a time in which 7 foot-levels accumulated. These two records on accumulation very likely represent closely similar time intervals. This means that the depression (boring 7) filled very rapidly by water wash from the adjacent steep slopes and by deposition of marl.

Pinus never reached abundance which indicates dense pine forests. This is in agreement with most pollen profiles from Early Wisconsin glacial areas in Indiana. The pollen record indicates that the accumulation of peat on the sandy ridge and the filling of the deep depression, as well as the shallower outer rim (boring 4) took place simultaneously perhaps soon after removal of the ice. Certainly, the whole area covered by the raised bog began accumulating before close of the Picea period (fig. 1).

PRESENT VEGETATION OF THE BOG

The present-day species occurring on the bog proper may roughly be divided into those which are typical of the general region in which the bog is located and those which are limited, in this region, to the bog area. The species of this latter group are preceded in the list below, with either an asterisk (*) or a number corresponding to a distributional group to be discussed in the following paragraphs. The nomenclature used is that of Deam's Flora of Indiana with subsequent modifications as published in "Indiana Plant Distribution Records." (Deam et al., 4)

Among the species limited to the bog proper, five distributional features are illustrated, viz., (1) prairie species, (2) species on the northern limits of their distribution, (3) species on the southern limits of their distribution, (4) disjuncts, (5) typical bog shrubs.

Perhaps the most striking feature of the more elevated portion of the bog is the very high percentage of its area occupied by prairie species. Among these are: *Andropogon gerardi, A. scoparius, Sorghastrum nutans, Filipendula rubra, Dodecatheon meadia, Silphium terebinthinaceum,* and *Aster praealtus* var. *angustior.* Gordon (7) found a similar situation on the Urbana bog. Another striking feature is the absence of ericads.

Two species of southern distribution in Indiana are on the northern limits of their range on this bog. *Melica nitens* is present in a large luxuriantly growing colony on the leeward slope of the crest of the highest elevation. It is here growing only short distances from the drainage ditch of one of the permanenty-flowing artesian springs. *Viburnum dentatum* var. *deamii* is found in a small colony on a peat deposit which has encroached upon an arm of a gravel ridge extending into the bog from the southeast corner. This colony is also only a short distance from another of the numerous artesian springs of the elevated portion of the bog. A considerably larger colony of this shrub is found in a wet area about 11 miles southwest of the bog, just across the county line in Henry county.

Among the species of northern distribution, four are here on the southern limits of their range, viz., *Muhlenbergia setosa, Juncus brachycephalus, Cypripedium reginae,* and *Aster umbellatus.* The last named species also occurs in disjunct colonies on the Illinois Drift Plain four counties farther south. By far the larger number of northern species of special interest occurring on the bog are disjuncts in this area. Among these disjuncts are: *Panicum albemarlense* known elsewhere in Indiana only near the northwest corner of the state in Porter, Jasper, and Pulaski counties and in Kosciusko county (in the north central part of the state); *Panicum implicatum* occurring here and in adjoining Henry county, three counties south of its general distribution; *Hierochloe odorata* four counties south of its general distribution; *Eleocharis rostellata* occurring here and in Henry county, four counties south of its general distribution; *Rhyncospora capillacea* occurring here and in Henry and Wayne counties, four counties south and southeast of its general distribution.

Other species exhibiting similar disjunct distribution are: *Triglochin palustris, Tofieldia glutinosa, Salix lucida, Lathyrus palustris, L. palustris* var. *linearifolius, Gerardia purpurea, G. paupercula* var. *typica, Chelone glabra* var. *linifolia* forma *velutina, Lobelia kalmii,* *Bidens connata* var. *petiolata,* and *Prenanthes racemosa.* Another species which is both very rare and local in Indiana and which occurs here is *Melanthium virginicum.*

Among the typical bog shrubs of the area are to be found: *Salix lucida, Rhus vernix, Rhamnus lanceolata, Potentilla fruticosa, Cornus stolonifera,* and *Viburnum lentago. Physocarpus opulifolius* and *Corylus americana* are also abundant on the bog.

Three species of Chara are found growing in the lime-charged water flowing from the numerous artesian springs. Most common of these are *Chara foetida* and *C. contraria.* Of unusual interest is *Chara brittoni* which has been determined by Mrs. Fay Daily and, so far as is at present known to her, is known only from the type specimen except for this location on the Cabin Creek bog and another on the Mill Creek bog, in La Porte County, Indiana.

LIST OF SPECIES OCCURRING ON CABIN CREEK BOG

In the following list are given those species which occur on the bog proper. Species preceded with either an asterisk or a number are found only on the bog. Others occur in the region off the bog as well as upon it. Species preceded with "1" are prairie plants; with "2" are on the northern limits of their range in Indiana; with "3" are on the southern limits of their range in Indiana; with "4" are disjuncts; and with "5" are typical bog shrubs.

Onoclea sensibilis

Equisetum arvense
1 Andropogon gerardi
1 Sorghastrum nutans
1 Panicum implicatum
4 Muhlenbergia setosa
Sphenopholis intermedia
Dactylis glomerata
Glyceria striata
* Cyperus odoratus
4 Eleocharis rostellata
* Scleria verticillata
Carex vulpinoidea
4 Juncus brachycephalus
4 Tofieldia glutinosa
Smilacina racemosa v. typica
Polygonatum canaliculatum
Trillium sessile

* Dryopteris thelypteris pubescens
Sparganium eurycarpum
4 Triglochin palustris
1 Andropogon scoparius
4 Panicum albemarlense
4 Hierochloe odorata
* Phragmites communis
2 Melica nitens
Poa sylvestris
* Cyperus odoratus
Scirpus atrovirens
4 Rhyncospora capillacea
Carex hystercina
Symplocarpus foetidus
Juncus torreyi
* Melanthium virginicum
Smilacina stellata
Trillium flexipes
T. flexipes f. walpolei

Hypoxis hirsuta
3 Cypripedium reginae
* Populus tremuloides
Salix discolor v. latifolia
Corylus americana
Ulmus americana f. alba
* Humulus americana
* Boehmeria cylindrica v. drummondiana
Commandra richardsiana
Acnida altissima
Claytonia virginica
Caltha palustris
Ranunculus hispidus
R. recurvatus
* Cardamine bulbosa
5 Physocarpus opulifolius
1 Filipendula rubra
Agrimonia parviflora
Prunus americana
5 Potentilla fruticosa
* Apios americana
Geranium maculatum
Rhus glabra
5 R. vernix
Hypericum mutilum
Ludwigia palustris v. americana
Zizea aurea
Thaspium barbinode
* Oxypolis rigidior
Lysimachia ciliata
* L. longifolia
1 Dodecatheon meadia
* Gentiana procera
* Phlox maculata
Polemonium reptans
Verbena hastata
Stachys tenuifolia v. hispida
* S. tenuifolia v. platyphylla
Physalis subglabrata
Mimulus alatus
4 Gerardia paupercula v. typica
4 G. purpurea
2 Viburnum dentatum v. deamii
5 V. lentago
Valerianella intermedia
Lobelia siphilitica
* Liatris spicata
Iris virginica v. shrevei
Spiranthes cernua
Salix cordata
4 Salix lucida
Quercus bicolor
Q. muhlenbergii
Laportea canadensis
Parietaria pennsylvanica

Polygonum persicaria
P. punctatum
* Arenaria lateriflora
* Aquilegia canadensis v. coccinea
Thalictrum revolutum
Heuchera americana v. brevipetala
4 Parnassia glauca
* Geum laciniatum
G. vernum
Rosa palustris
Cassia hebecarpa
4 Lathyrus palustris
4 L. palustris v. linearifolius
Euphorbia commutata
Impatiens biflora
5 Rhamnus lanceolata
Viola papilionacea
Circaea quadrisulcata v. canadensis
Cicuta maculata
* Angelica atropurpurea
5 Cornus obliqua
Cornus racemosa
5 C. stolonifera
Fraxinus americana
* Fraxinus nigra
F. quadrangulata
Hydrophyllum virginianum
* Physostegia virginiana
Monarda fistulosa
* Pycnanthemum virginianum
4 Chelone glabra v. linifolia
4 C. g. var. 1. forma velutina
* Pedicularis lanceolata
Galium asprellum
G. triflorum
* Lonicera prolifera
4 Lobelia kalmii
* Eupatorium maculatum
E. perfoliatum

Solidago altissima
S. canadensis v. gilvocanescens
* S. ohioensis
* S. patula
* S. riddellii
* S. uniligulata
Ambrosia elatior
A. trifida
* Helianthus giganteus
Helenium autumnale
H. a. var. parviflorum
* Cacalia tuberosa
* Cirsium muticum
* Prenanthes altissima
4 P. racemosa
E. rugosum
Aster novae-angliae
1 A. praealtus v. angustior
3 A. umbellatus
Erigeron philadelphicus
Silphium integrifolium
1 S. terebinthinaceum
Rudbeckia hirta
Bidens comosa
4 B. connata v. petiolata
B. coronata
* Senecio aureus v. intercursus
Cichorium intybus

CHARACTER OF THE BOTTOM OF THE BOG

Figure 2 shows four transects taken along eight radii from the deepest part of the bog. All four transects show that the peat and marl have been deposited upon a considerably dissected base. The numbers at the base of each transect represent the boring numbers whose depths are represented on each transect. The broken line represents the level of the margin of the bog (nearest Cabin Creek) which was taken as the bench mark for determining all other elevations and depressions. The west-east transect passes through the deepest depression (as do all of the transects) and also the highest elevation of the deposit. The latter is at boring no. 1 and is 10 feet above the bench mark. Boring no. 52, on the southwest-northeast transect, showed an elevation of 9 feet 6 inches and boring no. 5, on the northwest-southeast transect, showed an elevation of 9 feet 3 inches. These three borings are on a nearly straight line running a little west of north to a little east of south, as may be seen by reference to figure 4, in which the location, elevation and depth of all borings are given. The first figures in the parentheses opposite the boring numbers are the elevations of the surface above the bench mark, while the second figures of each parenthesis are the depth of deposit below the bench mark. The bottoms of these three borings are 3 feet, 1 foot 6 inches, and 9 inches respectively below the bench mark level. These highest elevations are, apparently, on top of a sand ridge. In figure 2 it will be seen that the bog-bottom along the transect running west from the center passes through three pronounced ridges with alternating valleys after leaving the deep central valley.

The north-south transect (figures 2, 3 and 4) passes for the greatest distance through the deepest portion of the bog basin. Borings no. 7 and 33-36 show depths below the bench mark of from 32 to 28 feet 10 inches. Apparently this was an ancient stream bed whose course was filled with glacial deposit on both the north end (borings 37-39) and the south end (borings 61-67). This valley remained about 150 feet wide after glacial till was deposited as may

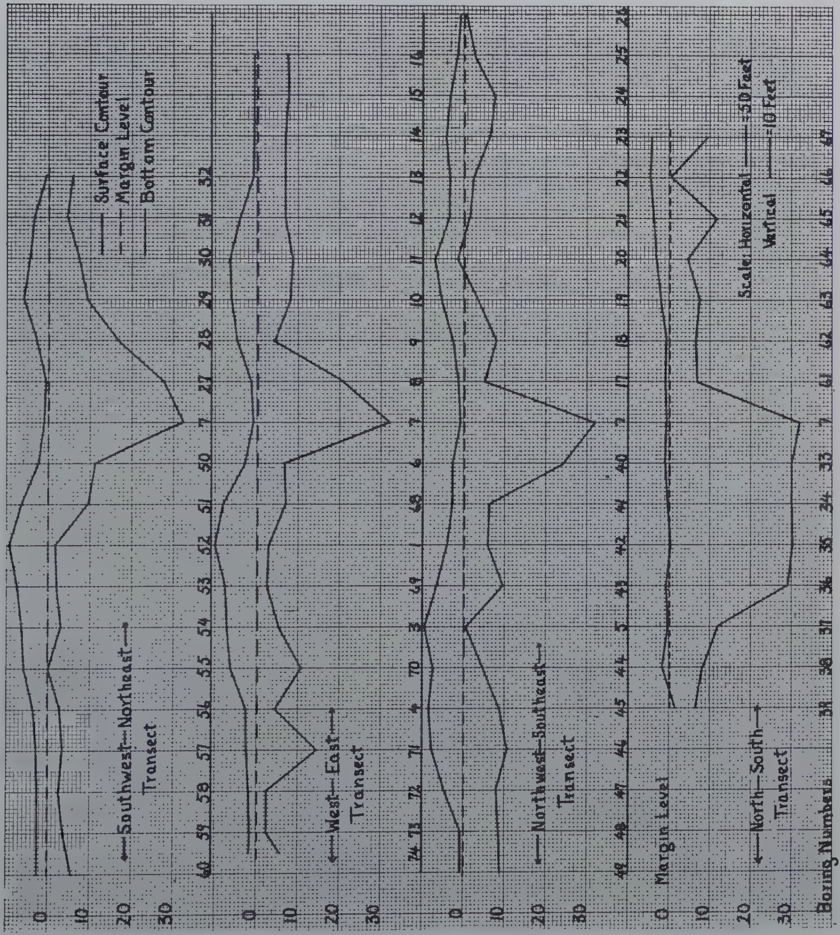

Fig. 2. Cabin Creek Bog. Four transects (eight radii) through center (boring 7) of bog. Broken lines represent the margin-level of the bog. Solid lines represent elevation above and depression below the margin-level for each boring.

be inferred from camparisons of the areas on figure 2, represented by borings 6-9 on the west-east transect, borings 41, 40, 7 and 17 on the northwest-southeast transect, and borings 50, 7, and 27-29 on the southwest-northeast transect. Figure 3 shows an attempt to construct a contour map of the base upon which the material of the

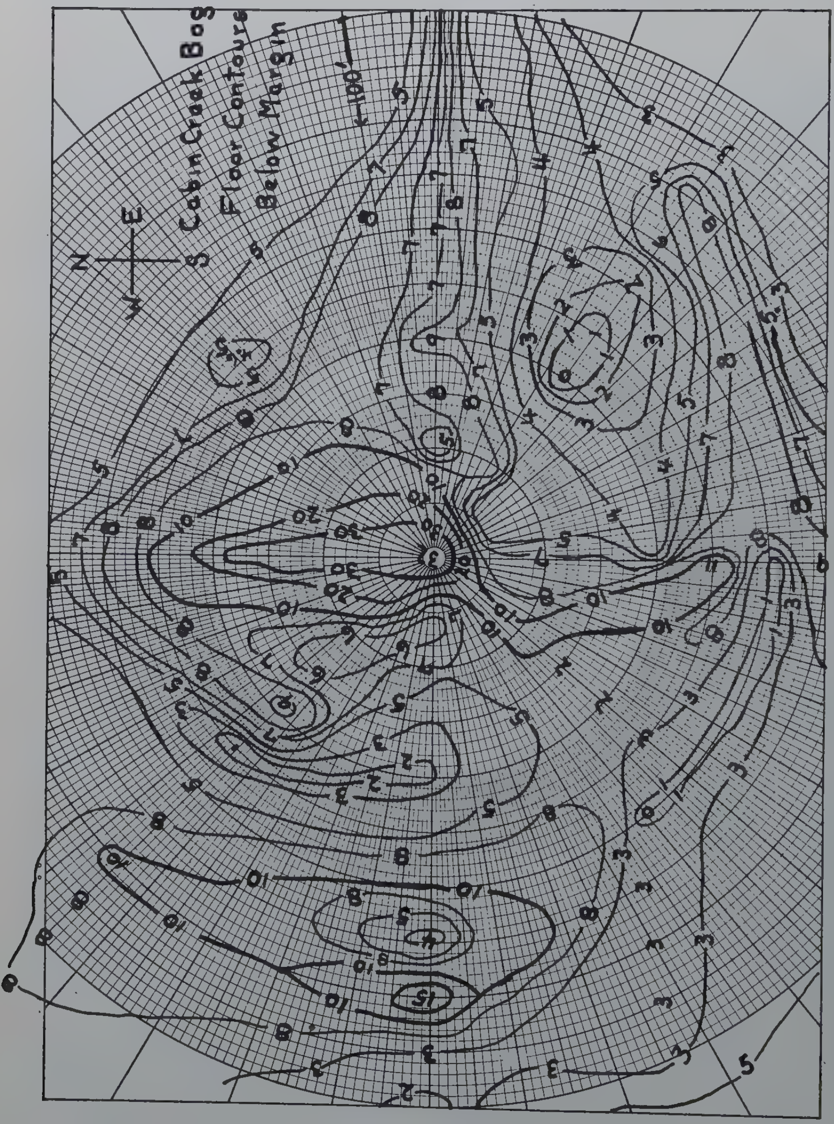

Fig. 3. Contour map of bottom of Cabin Creek Bog. Contour lines represent depth in feet below the margin-level of the bog.

bog has been deposited. This map must be considered to be only approximately accurate. It is based upon the 73 borings whose distribution is shown on the 8 radii of figure 4 and whose depths are represented in the transects of figure 2. The actual depths are

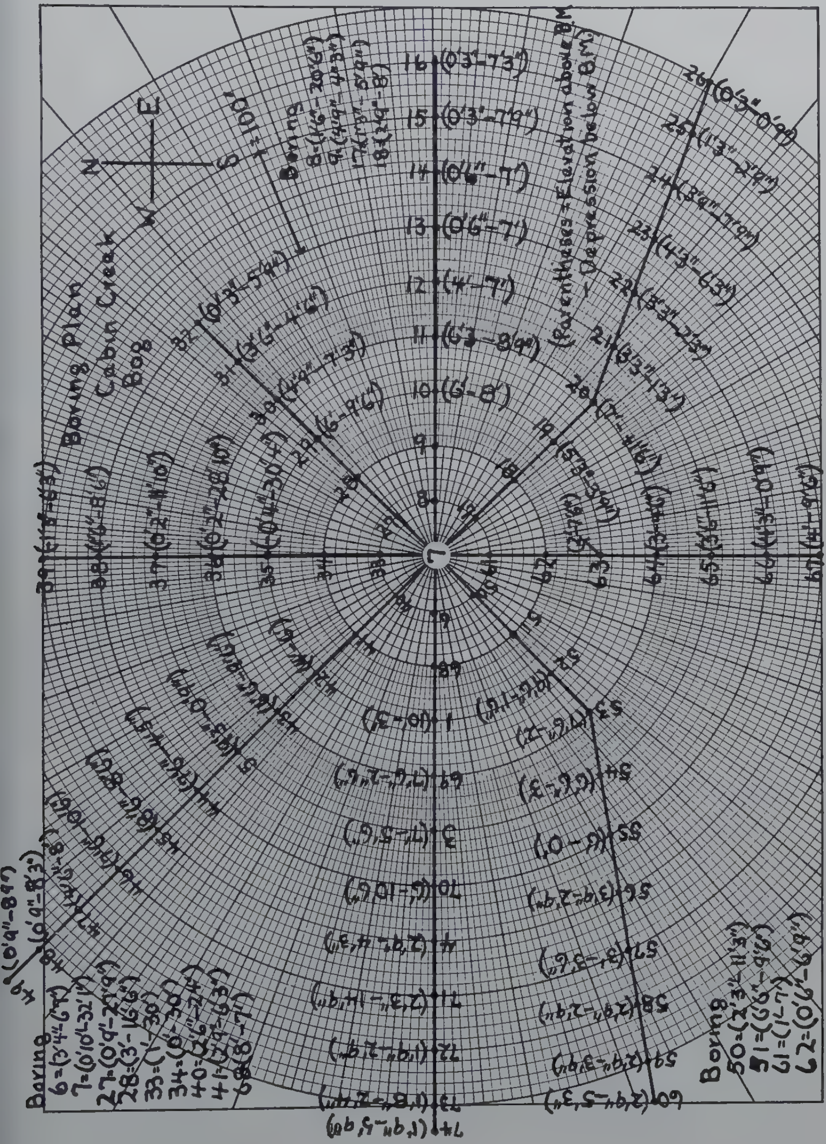

Fig. 4. Distribution of borings, Cabin Creek Bog. Fifures in parenetheses represent elevation of top and depth of bottom of borings, measured from the margin-level.

given in the parentheses opposite the boring numbers on figure 4. The contour lines are reasonably accurate on the 8 radii, but they are only approximately so on the areas between the radii. In spite of this inaccuracy, the contour map will give the reader a better concept of the character of the base upon which deposition has been made than mere descriptive words could convey.

DISCUSSION

The pollen profiles serve a dual purpose in this investigation, first of all they are the only means to know something specific about the climatic and vegetational changes since glacial times in the Randolph County area, and secondly they roughly date the time of initiation of sedimentation in the bog. Even though sediments were examined from borings of widely different depths, beginning of accumulation of these sediments was quite simultaneous in all locations regardless of the depth of the base upon which deposition began. The rather limited number of foot-levels given to the forest changes since close of the Picea period hint at slackening pace of peat formation as the bog increased in height. No doubt the increasing height accelerated evaporation rate and this in turn increased oxidation of the plant remains. Sparse pollen representation in upper foot-levels favors such a conclusion.

Reports of raised bogs quite generally state that the elevation of the peat mass totals about 13 to 15 feet. This suggests the probability that such height is perhaps maximum for raised bogs, and oxidation under reduced water content counteracts accumulation of plant remains.

The history of the vegetation since close of the Picea period is compressed into 5 to 7 foot-levels in the Cabin Creek Bog while in the nearby Reed extinct lake it covers 25 foot-levels, which points, again, to retarded accumulation or partial destruction of plant debris as the bog mass became elevated.

The forest changes as well as the composition of the several associations shown by pollen profiles from Cabin Creek Bog add no particular new features to records reported in previous studies of bogs located in territory of Early Wisconsin glaciation in Indiana. The Picea period is usually long, Pinus seldom reaches a pollen representation which suggests a dominant position in the forest complex, and Quercus replaces the conifers without important fluctuations.

Much can also be learned from the accumulated sediments. Water high in calcium carbonate is shown in the abundant marl infiltrations (table I). It is, however, difficult to explain absence of marl in one foot-level in boring 1, and absence of it in 6 foot-levels in profile 7. One is inclined to interpret the similarities in the accumulations as identical time of deposition (comparing level 7 in boring 1 with 12 in boring 7) but the difference in forest composition shown by the two pollen profiles makes such an explanation impossible. According to the pollen representation foot-level 4 in boring 7 and foot-level 6 in boring 1 are representing about the same time interval.

SUMMARY AND CONCLUSIONS

1. The paper presents a detailed study of the Cabin Creek raised bog in Randolph County, Indiana.
2. The configuration of the surface now covered by the peat mass was studied by means of borings made at 50-foot intervals along 8 radii, all of which passed through the centrally-located deepest place (boring 7).
3. The history of the vegetation and the time of initiation of deposition were determined with aid of pollen profiles from 3 borings.
4. Moisture is derived from springs which give rise to several small streams which flow from the peat mass at the present time.
5. Vegetational change was from *Picea glauca* and *P. mariana* to Pinus-Quercus to Quercus and other broadleaved genera.
6. Deposition of the peat and marl, even along the shallow outer rim, began during the Picea period.
7. In the deepest boring (33 feet) the Picea period involves 28 foot-levels and only 7 foot-levels in the nearby boring 1. This is interpreted as being due to more rapid accumulation during the open water stage in the deep depression than on the sandy ridge.
8. In the deepest boring (7), water-deposited material involves 20 foot-levels. Peat is of three types from the standpoint of origin, viz., moss, sedge, and wood, and combinations of these. Moss (Drepanocladus) was an important peat former in lower levels but not in the topmost levels.
9. Marl is abundant except at foot-level 7 in boring 1 and at 6 foot-levels in boring 7.
10. The conclusion is drawn that the 33-foot and 13-foot borings are best dated by their pollen profiles and not by nature of similar sediments.

11. The present vegetation presents a number of interesting features. Among them are: the very large percentage of coverage by prairie species; the total absence of ericads; the presence of a considerable number of disjunct colonies of species whose general distribution is three or four counties farther north or northwest.

12. The bottom upon which deposition of bog materials has been made is much dissected and appears to be a series of sand or gravel ridges alternating with depressions which are often both deep and with steep sides.

ACKNOWLEDGMENTS

Grateful recognition is made of assistance given during the difficult boring work by Messrs. Carl O. Keller and D. E. Sloan.

To the owner of the farm on which the bog is located, Mr. Walter W. Hudgel, we are grateful for the ready permission granted us to carry on the study. We also acknowledge gratefully the information given us by Mr. Earl James, tenant on the Hudgel farm. Especially have we appreciated the scientific interest and understanding, the ever cordial welcome, the keen observation and valuable information given by Mr. Chas. L. Hawkins, the neighbor across the highway. To both Mr. and Mrs. Hawkins we are indebted for many kindnesses and hospitality shown while the investigation was in progress.

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TABLE I

Nature of sediment in borings of Cabin Creek Bog.

Foot Level	Color	Degree of Marliness (HCl Test)	Nature of Sediment
		Boring 7	
1	black (brownish tint)	none	mainly wood
2	black	none	wood-sedge
3	dark-brown	none	wood
4	black	1	wood
5	dark-brown	none	wood
6	almost black	none	wood
7	dark-brown	none	wood
8	grayish-brown	2	moss-sedge (some wood)
9	dark-reddish	4	wood-sedge
10	dark-gray	4	wood-sedge
11	dark-gray	3	sedge
12	grayish-brown	2	moss-sedge
13	gray (oxidizes brown)	4	very little organic material
14	grayish-brown	4	"
15	gray	4	"
16	gray	4	"
17	dark-gray	4	"
18½	dark-brown	4	"
19½	dark-gray	4	"
20	dark-gray	4	"
21	dark-gray	4	"
22	grayish-brown	3	"
23	grayish-brown	3	"
24	dark-brown	2	"
25½	reddish	4	"
26	reddish	4	"
27	reddish	4	"
28	pitch-black, paint-like, oxidizing brown	3	"
29	"	2	"
30	reddish-brown	2	"
31	pitch-black, paint-like	4	"
32	grayish-brown	3	"
		Boring 1	
1	dark-brown	4	sedge-wood
2	gray	4	sedge-wood
3	dark grayish-brown	4	sedge
4	dark-brown	3	sedge
5½	dark-brown	2	sedge
6	grayish-dark-brown	4	sedge

TABLE I—(Continued)

Foot Level	Color	Degree of Marliness (HCl Test)	Nature of Sediment
7	dark-brown	none	wood, some sedge
8	dark-brown; streaked gray	4	sedge, some moss
9	"	4	sedge-moss
10	"	4	sedge-moss
11	"	4	sedge-moss
12	grayish-brown	4	moss
13	gray	4	some moss, sand, marl
		Boring 5	
Surface	black	1	finely divided wood
1	black with lighter areas	2	"
2	black	none	wood-sedge
3	blackish-gray	2-3	wood-sedge
4	dark-gray	1	wood-sedge
5	black	none	wood-sedge
6	gray	3	finely divided wood
7	dark-brown	2	moss-wood
8	dark-gray	3	moss-wood
9	dark-gray	3	moss-wood
10	brownish-gray	2	moss, finely divided wood
		Boring 6	
6½	brownish-gray	4	wood
7½	dark-gray	4	wood, ooze
9	gray	4	wood, some sedge
10	light-brown	4	mostly inorganic, small pieces of wood
		Boring 4	
Surface	black	none	woody
1	black	none	woody
2	black	none	woody
3	black	none	woody
4	dark-gray	none	wood, sand
5	dark-gray	1	mainly inorganic
6	gray, oxidizing reddish	1	wood
7	reddish-brown	1	mainly inorganic, small particles of wood

A STUDY OF THE DISTRIBUTION OF THE GRASSES OF INDIANA

By Howard L. Cook

Deam (1) has shown that the flora of Indiana comprises nearly 2,000 species of which approximately 40% of the native forms are on the limits of their range in Indiana. Friesner (8) has shown that Indiana is a critical botanical area, having approximately 45% of its present-day species on the limits of their range within the state. For the purposes of this paper, such plants are considered to be extraneous species. Apparently, this critical nature of Indiana plant distribution applies to all of the higher types of vegetation: ferns, trees, shrubs, grasses and other herbaceous forms. Lindsey (10) has shown that it applies to the trees, 41% of which are extraneous. The mass distribution of these extraneous tree species lies in three general directions from Indiana, viz., northeast, south and southeast. Trefz (11) has likewise shown that it applies to the shrubs, 56% of which are extraneous, with mass distribution of the extraneous forms lying in four general directions from Indiana, viz., north, northeast, northwest and west in order of decreasing importance from the standpoint of numbers. Deam (1) has shown that the distribution of the total extraneous flora lines in nine directions, viz. (in order of decreasing numbers), north, south, west, southwest, east, Atlantic coastal, northeast, northwest and southeast.

The present study was undertaken to determine how the grasses fit into this picture.

INDIANA BOTANICAL AREAS

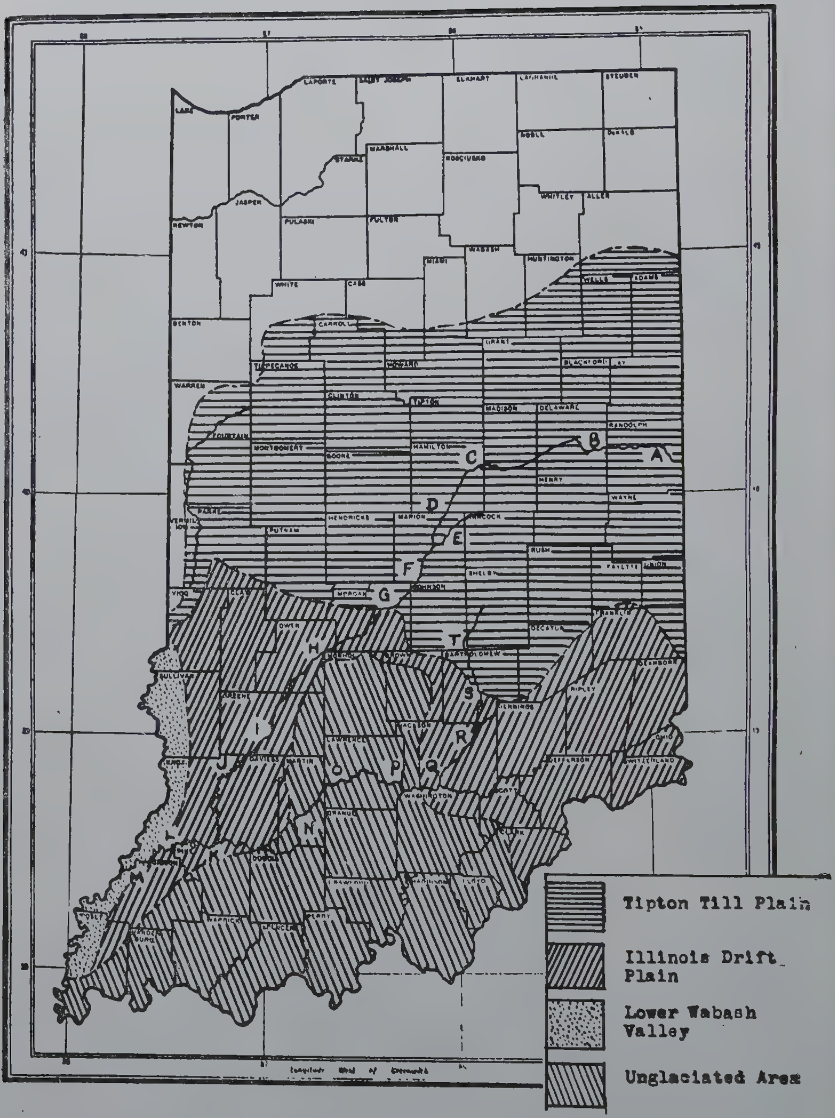
For convenience in discussing distribution within the state, the six botanical areas into which Deam (2) has divided the state were used. The accompanying map shown by Guss (9) was used. Description of these areas is based upon Deam (2). The Lakes area presents a variety of habitats. Here are found bogs and marshes, sandy and gravelly areas, prairies and their remnants, mesophytic forests, numerous lakes and river habitats. The Tipton Till Plain is not considered strictly a botanical area by Deam. The area is relatively level, being marked here and there by numerous terminal moraines. The soil acidity factor, neutral to slightly acid, probably explains why many plants from the Illinois Drift Area have not entered the Tipton Till Plain. The soil of the Illinois Drift Area is much more acid. Cultivation of the soil of this area has eliminated many species and caused others to become rare. Many Lakes Area plants remain as relics in the extinct lake areas and springy places of the Tipton Till Plain.

The Illinois Drift Area is divided into eastern and western lobes which are, for the most part, separated from each other by the intervening Unglaciated Area. The topography consists of level areas and, where more dissected, of deeply cut ravines. The "Flats" in the eastern lobe of the area are level, poorly drained areas and the soil is acid, presenting a barrier to plants unable to tolerate this type of soil. Sand dunes are found in the western lobe and this part of the area is generally better drained. The Prairie Area has been so intensely cultivated that its few remaining original species are confined to roadsides, railroad rights-of-way, cemeteries, and other uncultivated sites.

The Lower Wabash Valley is a narrow fringe of alluvial soil on the east bank of the Wabash River from Parke County southward to the Ohio River. A portion also extends up the Ohio River to Little Pigeon Creek in Warrick County. The Wabash River periodically inundates the entire area at flood stage. The Unglaciated Area may be divided into an eastern and a western part. The western part is included in the Wabash lowland and its eastern boundary is Anderson Creek to St. Meinrad thence northwestward to the glacial boundary. The eastern section of this area consists, for the most part, of hills and high ridges with intervening deep ravines and valleys. These high ridges are often referred to as the "Knobs."

METHOD OF STUDY

The Indiana grass flora, according to Deam (3-7), comprises 227 species, varieties and forms. These have been studied from the standpoint of their distribution both within and outside the state. For the purpose of this paper, plants which, somewhere on the periphery of their range, do not extend beyond Indiana are considered to be extraneous species. Those whose general distribution occurs on all sides of Indiana, i. e., whose periphery of distribution does not pass through Indiana, are considered to be intraneous species. Table II lists the extraneous species showing their distribution according to


Tipton Till Plain
Illinois Drift Plain
Lower Wabash Valley
Unglaciated Area
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
LAKE
PORTER
LAPORTE
STARKE
MARSHALL
ELKHART
KOSCIUSKO
NOBLE
STEUBEN
WHITLEY
ALLEN
JASPER
NEWTON
PULASKI
FULTON
WABASH
HUNTINGTON
MIAMI
WHITE
CASS
WELLS
ADAMS
BENTON
CARROLL
GRANT
TIPPECANOE
HOWARD
WARREN
CLINTON
TIPTON
MADISON
DELAWARE
RANDOLPH
FOUNTAIN
MONTGOMERY
BOONE
HAMILTON
HENRY
WAYNE
PARKE
HENDRICKS
MARION
HANCOCK
PUTNAM
RUSH
FAYETTE
UNION
SHELBY
VIGO
CLAY
MORGAN
JOHNSON
OWEN
DECATUR
FRANKLIN
BROWN
BARTHOLOMEW
DEARBORN
SULLIVAN
GREENE
RIPLEY
JENNINGS
JACKSON
LAWRENCE
OHIO
DAVIESS
MARTIN
JEFFERSON
SWITZERLAND
KNOX
WASHINGTON
SCOTT
ORANGE
CLARK
DUBOIS
CRAWFORD
HARRISON
FLOYD
POSEY
VANDERBURGH
WARRICK
SPENCER
PERRY

botanical areas within the state and to direction of distribution outside the state. Nomenclature follows that of Deam (3-7). The listing in tables II and III is according to tribes and alphabetically within tribes.

EXTRANEOUS SPECIES

Extraneous forms comprise 141 species and constitute 62% of the total grass flora of the state. Table IV is an arrangement of the extraneous species into distribution types on the basis of their general distribution outside the state. The total grass flora is broken into 39 distribution types. All members of any particular type have the same general range (outside the state) with respect to compass direction. Distribution type no. 1 comprises species occurring only northwestward outside Indiana and contains *Panicum deamii* only. The species occurring in each distribution type are cited by species number, these being the numbers assigned to them in table II. Distribution types are regrouped into 12 group types. Distribution types 1 to 6, for example, having a maximum range from west clockwise to east (by the compass) or within those limits, becomes group type I and comprises 36 species.

The 36 species comprising group type I represent about 25% of the total extraneous species and about 16% of the total grass flora. Distribution types 3 and 4 of this group comprise 23 species which are found largely in the Prairies and Lakes Area.

Group Type X has 32 species distributed along seven directions of the compass outside Indiana. Their distribution is general throughout the state. This group comprises about 14% of the total species and about 23% of the total extraneous species. Species of group type IX extend in six directions outside Indiana and are 29 in number. This is 20% of the extraneous species and 12% of the total grass flora. Their Indiana distribution is general throughout the state. The remaining group types are represented by not more than 10 species each.

Of the total number of extraneous species of grasses in the state 98 or 70% are found in the Lakes Area, 90 or 64% in the Prairie Area, 78 or 55% in the Tipton Till Plain, 74 or 52% in the Unglaciated Area, 72 or 51% in the Illinois Drift Plain, and 48 or 34% in the Lower Wabash Valley. This is shown graphically in table I.

TABLE I

Distribution of Extraneous Species according to Botanical Areas within the State.

Botanical Areas	Number of Species	Percentage of Total Extraneous Species
Lakes Area	98	70
Prairie Area	90	64
Tipton Till Plain	78	55
Unglaciated Area	74	52
Illinois Drift Plain	72	51
Lower Wabash Valley	48	34
All Areas	141	100

INTRANEOUS SPECIES

Eighty-six species (38% of the total) are distributed along all eight points of the compass outside Indiana. Of these intraneous species 71 or about 83% are found in all botanical areas of the state. An additional 14% of the total species have a distribution outside Indiana along seven of the eight compass directions used in this study. Since 38% of the total species are completely intraneous, this additional 14% makes a total of 52% of the grasses which are practically intraneous.

DISTRIBUTION OF THE TOTAL GRASSES OF THE STATE

Table V gives the number of extraneous and intraneous species found in each botanical area of the state. It will be noted that in the Lakes Area are found 79% of the total grasses of the state, 93% of the intraneous species and 70% of the extraneous species. The Prairie Area follows with 75% of the total, 91% of the intraneous and 64% of the extraneous species. The Tipton Till Plain is third with 68% of the total, 88% of the intraneous and 55% of the extraneous species. The Illinois Drift Plain and the Unglaciated Area are strikingly similar in regard to numbers of both intraneous and extraneous species. Each had 67% of the total species while they have 92% and 91% respectively of the intraneous, and 51% and 52% respectively of the extraneous species.

The Lower Wabash Valley contains the smallest number of species of all the areas. Fifty-nine per cent of the total species have been reported for the area. The low number of species found here is probably due in part to the small size of the area, but much more to the fact that the Wabash River periodically floods the area which eliminates those species which cannot survive such conditions.

Reference to table II shows that 39 species, varieties or forms are limited to one botanical each. Of these, 7 are limited to the Unglaciated Area, viz., *Glyceria acutiflora, Melica mutica, Poa cuspidata, Hordeum nodosum, Panicum yadkinense, P. mattamuskeetense,* and *Muhlenbergia capillaris.* Twenty-two forms are limited to the Lakes Area, viz., *Bromus brizaeformis, B. ciliatus* f. *denudatus, B. mollis, Glyceria pallida, Amophila breviligulata, Aristida tuberculosa, Milium effusum, Muhlenbergia foliosa* f. *ambigua, Oryzopsis asperifolia, O. pungens, Panicum auberne, P. columbianum, P. deamii, P. lucidum, P. meridionale, P. scoparioides, P. subvillosum, P. verrucosum, P. longifolium, Zizania aquatica* var. *interior, Stipa avenacea,* and *S. comata.* The presence of this last-named species on a gravelly slope above Diamond Lake in Noble County is difficult to harmonize with its absence in prairie sites farther west in the state. It may be a relic of a retreating prairie flora. Two species, viz., *Festuca capillata* and *Muhlenbergia cuspidata* are limited to the Prairie area and two are limited to the Tipton Till Plain, viz., *Schizachne purpurascens* and *Poa nemoralis.*

TABLE V

Summary of Distribution of the Grasses within Botanical Areas of the State.

Areas	Extraneous Number of Species	Extraneous %	Intraneous Number of Species	Intraneous %	Total Species Number	Total Species %
Prairie	90	64	78	91	168	75
Lakes	98	70	80	93	178	79
Tipton Till	78	55	76	88	154	68
Illinois Drift	72	51	79	92	151	67
Unglaciated	74	52	78	91	152	67
Lower Wabash Valley	48	34	77	90	135	59

Erianthus saccharoides v. *compactus, Muhlenbergia sobolifera* f. *setigera,* and *Gymnopogon ambiguus* are limited to the Illinois Drift Plain while *Leptochloa panicoides* and *Festuca paradoxa* are limited to the Lower Wabash Valley.

Table II also shows 17 forms which are limited in their state distribution to two botanical areas each. Of these, 12 are found in the Prairie and Lakes Areas, 2 in the Illinois Drift Area and the Unglaciated Area, and one each in the following combinations of areas: Prairie with Tipton Till Plain, Lakes with Tipton Till Plain, and Lakes with Illinois Drift Area.

From these data it might be concluded that the Prairie and Lakes Areas have more selective habitats and are thus more critical botanical areas than the other areas of the state. Such a conclusion is in accord with conclusions of Friesner (8) who showed that the Lakes Area possesses both a larger percentage of the total flora of the state and a very much higher percentage of the extraneous species than any other area.

The mass distribution of the Indiana grasses outside the state shows 90% of the total grass flora to extend northeastward from the state, 84% to extend eastward, 85% westward, 80% northwestward and 75% northward. The weakest affinity (67%) is southward, with southwest showing 70% and southeast 72%. Thus, while the grasses show the strongest affinity northeastward, Lindsey (10) found the same direction to be strongest for trees and Trefz (11) found north to be strongest and northeast second in the case of the shrubs. These data are summarized in tables VI and VII.

Indiana has no species of grasses wholly endemic to the state. The species coming nearest to being endemic are: *Panicum deamii,* found only in Iowa outside Indiana; *Muhlenbergia sobolifera* f. *setigera,* found only in Arkansas and Texas outside Indiana; and *Leptochloa panicoides,* a rare species found only in Posey County and in Mississippi, Louisiana, and Texas, in the United States outside Indiana.

TABLE VI

Mass Distribution and Percentage of Extraneous Forms in Total Flora, Trees, Shrubs, and Grasses.

Authority	Group Studied	% Extraneous	Direction of Mass Distribution Outside the State
Deam (1) 1924	Total Flora	40	North, south, west, east, Atlantic coastal, northeast, northwest, southeast
Friesner (8) 1936	Total Flora	45	
Lindsey (10) 1932	Trees	41	Northeast, south and southeast
Trefz (11) 1935	Shrubs	56	North, northeast, northwest and west
Cook (present paper)	Grasses	62	Northeast, east, west, northwest and north

TABLE VII

Distribution of Indiana Grasses outside the State.

Direction	Extraneous Species Number of Species	Percentage	Total Species Number of Species	Percentage
West	99	73	185	83
Northwest	91	67	177	80
North	82	60	168	75
Northeast	112	82	198	90
East	101	74	187	84
Southeast	75	55	161	72
South	63	46	149	67
Southwest	76	56	152	70

The Indiana grass flora contains a number of species characteristic of the lowland areas of the Atlantic and Gulf coastal states. Five of these species are limited, in Indiana, to one county each, viz., *Panicum auburne* (Porter County), *P. longifolium* (Starke), *P. lucidum* (Porter), *P. mattamuskeetense* (Lawrence), and *Erianthus saccharoides* Var. *compactus* (Perry). In addition, *Panicum verrucosum* is found in Porter and Jasper Counties only; while *P. yadkinense* is limited to the Unglaciated Area, and *P. albemarlense* to the Lakes Area and the Tipton Till Plain. *Arundinaria macrosperma* occurs in the Illinois Drift Area, the Unglaciated Area, and the Lower Wabash Valley; *Paspalum fluitans* is limited to the latter two areas and *Andropogon elliottii* occurs in the Illinois Drift Area and the Unglaciated Area.

Sixteen species are rare and limited to but single counties while an additional five species are limited to but two counties each. *Panicum longifolium* is limited to Starke County; *Festuca capillata* to Tippecanoe; *F. paradoxa* and *Leptochloa panicoides* to Posey; *Schizachne purpurascens* to Cass; *Muhlenbergia capillaris* to Harrison; *M. cuspidata* to Tippecanoe; *Stipa comata* to Noble; *Gymnopogon ambiuus* to Daviess; *Panicum mattamuskeetense* to Lawrence; *P. auburne* and *P. lucidum* to Porter; *P. scoparioides* and *P. subvillosum* to Lake; and *Erianthus saccharoides* var. *compactus* to Perry. *Glyceria acutiflora* is limited to Lawrence and Harrison Counties (Unglaciated Area); *Deschampsia caespitosa* to Porter and St. Joseph Counties (Lakes Area); *Oryzopsis pungens* and

O. asperifolia are both limited to Porter and La Porte Counties (Lakes Area); and *Panicum columbianum* is limited to Starke and Steuben Counties (Lakes Area).

Three species have probably disappeared from the state, viz.. *Schizachne purpurascens, Panicum auburne,* and *P. lucidum.*

SUMMARY AND CONCLUSIONS

1. There are 227 species, varieties and forms of grasses found outside of cultivation in Indiana.

2. Eighty-six or 38% of these grasses are intraneous to the state in their distribution.

3. Eighty-three per cent of the intraneous forms are found in all of the botanical areas of the state. Very little difference exists in the numbers of intraneous species found in each of the botanical areas of the state. The Tipton Till Plain is the lowest in numbers with 88% and the Lakes Area is the highest with 93% of the total number of intraneous species.

4. One hundred and forty-one, or 62%, of the total species are on the limits of their range in Indiana and are considered to be extraneous in their distribution. The largest number of these extraneous species (70% of them) occur in the Lakes Area. The other areas in order of decreasing percentages are: Prairie, 64; Tipton Till Plain, 55; unglaciated, 52; Illinois Drift, 51; Lower Wabash Valley, 34.

5. The Lakes Area contains the largest percentage of the total grass species of any area in the state (79%). The other areas in order of decreasing percentages are: Prairie, 75; Tipton Till, 68; Illinois Drift and Unglaciated, 67 each; and Lower Wabash Valley, 59.

6. Twenty-five per cent of the total extraneous species are distributed from west through north to east, or within those limits, outside Indiana.

7. The mass distribution of Indiana grasses shows strongest affinity to the northeast, viz., 90% of the species, varieties or forms. Other directions are: east, 84%; west, 83%; northwest, 80%; north, 75%; southeast, 72%; southwest, 70%; and south, 67%.

8. No grass species is endemic to the state though there are a few with very limited distribution outside the state.

9. A number of Atlantic or Gulf coastal species occur in the state.

10. Sixteen species are rare and limited to single counties and an additional five are found in but two counties each.

11. Three species have probably disappeared from the state.

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TABLE II

Distribution of extraneous species according to botanical areas within the state and in compass directions outside the state. P, Prairie; L, Lakes Area; TP, Tipton Till Plain; I, Illinois Drift Area; U, Unglaciated Area; LW, Lower Wabash Valley.

			Botanical Areas						Compass Directions					
Species	P	L	TP	I	U	LW	W.	NW	N	NE	E	SE	S	SW
1. Arundinaria macrosperma				x	x	x					x	x	x	x
2. Bromus brizaeformis		x					x	x	x	x	x			
3. B. ciliatus	x	x	x				x	x	x	x	x	x		x
4. B. c. f. denudatus			x				x	x	x	x	x			x
5. B. kalmii	x	x	x		x			x	x	x				
6. B. latiglumis	x	x	x	x	x		x	x	x	x	x	x		x
7. B. mollis		x					x	x	x	x	x			
8. Festuca capillata	x						x	x	x	x	x	x		
9. F. ovina	x	x	x	x	x		x	x	x	x	x	x		
10. F. paradoxa						x	x				x	x	x	x
11. Glyceria acutiflora					x					x	x	x		
12. G. borealis	x	x					x	x	x	x				
13. G. canadensis	x	x	x					x	x	x	x			
14. G. grandis		x	x				x	x	x	x	x	x		
15. G. pallida		x					x	x	x	x	x			
16. Melica mutica					x		x				x	x	x	x
17. M. nitens	x	x	x	x	x		x	x		x	x			x
18. Phragmites communis	x	x	x	x		x	x	x	x	x		x		x
19. Poa alsodes	x	x	x	x				x	x	x	x			
20. P. autumnalis			x	x	x		x		x	x	x	x	x	x
21. P. chapmaniana			x	x	x	x	x	x			x	x	x	x
22. P. cuspidata					x					x	x	x		
23. P. languida	x	x	x					x	x	x	x			

TABLE II—(Continued)

Species			Botanical Areas							Compass Directions				
	P	L	TP	I	U	LW	W	NW	N	NE	E	SE	S	SW
24. P. nemoralis			x					x	x	x	x			
25. P. paludigena		x		x				x	x	x				
26. P. palustris	x	x	x				x	x	x	x	x			
27. P. wolfii	x	x	x				x	x	x	x				
28. Schizachne purpurascens			x				x	x	x	x	x			
29. Triodia flava	x	x	x	x	x	x	x	x		x	x	x	x	x
30. Uniola latifolia	x		x	x	x	x	x			x	x	x	x	x
31. Agropyron pauciflorum	x	x					x	x	x	x	x			
32. A. repens	x	x	x	x	x		x	x	x	x	x			x
33. A. subsecundum	x	x					x	x	x	x	x			
34. Elymus riparius	x	x	x	x	x				x	x	x			x
35. E. villosus v. arkansanus		x	x	x			x			x	x		x	x
36. E. virginicus v. australis			x	x	x	x	x			x	x	x	x	x
37. E. v. var. glabriflorus		x	x		x		x			x	x	x	x	x
38. E. v. var. submuticus	x	x		x	x	x			x	x	x	x	x	x
39. Hordeum jubatum	x	x	x	x	x	x	x	x	x	x	x	x		x
40. H. nodosum					x		x	x		x			x	
41. Hystrix patula var. bigeloviana	x	x	x	x	x	x	x	x	x	x				x
42. Lolium perenne	x	x	x	x	x	x	x	x	x	x	x			
43. Arrhenatherum elatius	x	x	x	x	x		x	x	x	x	x	x	x	
44. Deschampsia caespitosa		x						x	x	x	x	x		
45. Holcus lanatus		x	x	x	x		x	x		x	x	x	x	x
46. Koeleria cristata	x	x					x	x	x	x				x
47. Agrostis elliottiana	x		x	x	x	x	x			x	x	x	x	x
48. A. palustris	x	x	x	x	x		x	x	x	x	x			
49. Alopecurus aequalis	x	x	x	x			x	x	x	x	x			

TABLE II—(Continued)

Species	Botanical Areas						Compass Directions							
	P	L	TP	I	U	LW	W	NW	N	NE	E	SE	S	SW
50. A. pratensis	x		x				x	x	x	x	x	x		
51. Ammophila breviligulata		x							x	x	x			
52. Aristida dichotoma		x	x	x	x	x	x			x	x	x	x	x
53. A. intermedia	x	x	x				x	x					x	x
54. A. longispica	x	x	x	x	x	x	x		x	x	x	x	x	x
55. A. ramosissima				x	x	x	x	x			x	x	x	x
56. A. tuberculosa		x					x	x	x	x	x	x		
57. Calamagrostis canadensis	x	x	x	x	x	x	x	x	x	x	x	x		
58. C. inexpansa	x	x					x	x	x	x				
59. Calamovilfa longifolia	x	x					x	x	x					
60. Milium effusum		x						x	x	x				
61. Muhlenbergia brachyphylla			x	x	x	x	x	x						x
62. M. capillaris					x		x			x	x	x	x	x
63. M. cuspidata	x						x	x	x	x				x
64. M. frondosa f. commutata	x	x	x	x	x	x	x	x	x	x	x			
65. M. glabriflora	x			x	x	x	x	x						x
66. M. mexicana	x	x	x	x	x	x	x	x	x	x	x	x		x
67. M. m. f. ambigua		x					x	x	x	x	x	x		x
68. M. setosa	x	x	x				x	x	x	x	x	x	x	
69. M. sobolifera	x		x	x	x	x	x	x		x	x	x	x	x
70. M. s. f. setigera				x										x
71. Oryzopsis asperifolia		x					x	x	x	x				
72. O. pungens		x					x	x	x	x				
73. O. racemosa		x		x	x			x	x	x	x			
74. Sporobolus asper	x	x	x	x	x	x	x	x		x	x		x	x
75. S. canovirens	x	x	x	x	x	x	x	x		x	x	x	x	x

TABLE II—(Continued)

Species			Botanical Areas							Compass Directions				
	P	L	TP	I	U	LW	W	NW	N	NE	E	SE	S	SW
76. S. cryptandrus	x	x	x		x		x	x	x	x	x		x	x
77. S. c. var. involutus	x	x	x		x		x	x	x	x	x		x	x
78. S. heterolepis	x	x					x	x	x	x				x
79. Stipa avenacea		x							x	x	x	x	x	x
80. S. comata		x					x	x						x
81. S. spartea	x	x	x				x	x	x	x				
82. Cynodon dactylon			x	x	x	x	x		x	x	x	x	x	x
83. Leptochloa filiformis				x	x	x	x			x	x	x	x	x
84. Gymnopogon ambiguus				x							x	x	x	x
85. Leptochloa panicoides						x							x	x
86. Spartina pectinata	x	x	x	x	x	x	x	x	x	x	x			x
87. Anthoxanthum odoratum		x	x	x	x	x	x		x	x	x	x	x	x
88. Hierochloe odorata	x	x	x				x	x	x	x				
89. Phalaris arundinacea	x	x	x	x	x		x	x	x	x	x	x		
90. Leersia lenticularis		x	x	x	x	x	x	x				x	x	x
91. Zizania aquatica	x	x	x				x	x	x	x	x	x	x	
92. Z. a. var. angustifolia	x	x	x				x	x	x	x	x			
93. Z. a. var. interior		x					x	x						x
94. Leptoloma cognatum	x	x	x	x	x	x	x	x		x	x	x	x	x
95. Panicum addisonii	x	x	x							x	x	x		
96. P. albemarlense	x	x	x					x	x	x	x	x		
97. P. anceps				x	x	x	x			x	x	x	x	x
98. P. ashei	x	x		x	x		x		x	x	x	x	x	x
99. P. auburne		x								x	x	x	x	
100. P. bicknellii			x	x	x				x	x	x	x		x
101. P. boreale	x	x	x					x	x	x				

TABLE II—(Continued)

Species	P	L	Botanical Areas TP	I	U	LW	W	NW	N	Compass Directions NE	E	SE	S	SW
102. P. boscii			x	x	x	x	x	x		x	x	x	x	x
103. P. b. var. molle			x	x	x	x	x	x		x	x	x	x	x
104. P. columbianum		x								x	x			
105. P. commutatum			x	x	x		x		x	x	x	x	x	x
106. P. deamii		x						x						
107. P. depauperatum var. psilophyllum	x	x						x	x	x	x			
108. P. flexile	x	x	x	x	x	x	x	x		x	x	x	x	x
109. P. gattingeri	x	x	x	x	x	x	x	x		x	x	x	x	x
110. P. implicatum	x	x	x				x	x	x	x				
111. P. latifolium	x	x	x	x	x	x	x	x	x	x	x	x		
112. P. leibergii	x	x					x	x	x	x				
113. P. lucidum		x							x	x	x	x	x	x
114. P. mattamuskeetense					x					x	x	x		
115. P. meridionale		x						x	x	x	x	x	x	
116. P. microcarponn		x	x	x	x	x	x		x	x	x	x	x	x
117. P. oligosanthes	x	x		x		x	x	x		x	x	x	x	x
118. P. perlongum	x	x					x	x	x					x
119. P. polyanthes			x	x	x	x	x			x	x	x	x	x
120. P. praecocius	x	x		x	x		x	x	x					x
121. P. pseudopubescens	x	x	x				x	x	x	x	x	x	x	
122. P. scoparioides		x						x	x	x				
123. P. sphaerocarpon	x	x	x	x	x		x		x	x	x	x	x	x
124. P. spretum	x	x								x	x	x	x	x
125. P. stipitatum				x	x					x	x	x	x	x
126. P. subvillosum		x					x	x	x	x				
127. P. tsugetorum	x	x						x	x	x	x	x		

TABLE II—(Continued)

Species	Botanical Areas								Compass Directions					
	P	L	TP	I	U	LW	W	NW	N	NE	E	SE	S	SW
128. P. verrucosum		x								x	x	x	x	
129. P. xalapense				x	x	x	x				x	x	x	x
130. P. yadkinense					x						x	x	x	
131. P. longifolium		x								x	x	x	x	
132. Paspalum circulare			x	x	x	x	x			x	x	x	x	x
133. P. fluitans				x	x	x						x	x	x
134. P. pubiflorum v. glabrum				x	x	x	x				x	x	x	x
135. P. stramineum	x	x	x				x	x	x					x
136. Setaria verticillata	x	x	x	x	x		x	x	x	x	x		x	x
137. Andropogon elliottii				x	x						x	x	x	x
138. A. virginicus			x	x	x	x	x			x	x	x	x	x
139. Erianthus saccharoides var. compactus				x							x	x	x	x
140. Sorghum halapense	x	x	x	x	x	x	x	x		x	x	x	x	x
141. S. vulgare v. drummpndii			x	x	x	x	x	x		x	x	x	x	x

TABLE III

Distribution within the state of Intraneous species.

Species	P	L	TP	L	U	LW
1. Bromus commutatus	x	x	x	x	x	x
2. B. inermis	x	x	x	x	x	x
3. B. japonicus	x	x	x	x	x	x
4. B. purgans	x	x	x	x	x	x
5. B. secalinus	x	x	x	x	x	x
6. B. sterilis	x	x	x	x	x	x
7. B. tectorum	x	x	x	x	x	x
8. Dactylis glomerata	x	x	x	x	x	x
9. Diarrhena americana	x	x	x	x	x	x
10. Eragrostis capillaris				x	x	x
11. E. cilianensis	x	x	x	x	x	x
12. E. frankii	x	x	x	x	x	x
13. E. hypnoides	x	x	x	x	x	x
14. E. pectinacea	x	x	x	x	x	x
15. E. spectabilis	x	x	x	x	x	x
16. Festuca elatior	x	x	x	x	x	
17. F. obtusa	x	x	x	x	x	x
18. F. octoflora		x		x	x	x
19. F. o. var. tenella	x	x	x	x	x	x
20. Glyceria septentrionalis	x	x	x	x	x	x
21. G. striata	x	x	x	x	x	x
22. Poa annua	x	x	x	x	x	x
23. Poa compressa	x	x	x	x	x	x
24. P. pratensis	x	x	x	x	x	x
25. P. sylvestris	x	x	x	x	x	x
26. Agropyron smithii	x	x	x	x	x	x
27. Elymus canadensis	x	x	x	x	x	x
28. E. villosus	x	x	x	x	x	x
29. E. virginicus	x	x	x	x	x	x
30. E. v. var. intermedius	x	x	x	x	x	x
31. Hordeum pusillum	x	x	x	x	x	x
32. Hystrix patula	x	x	x	x	x	x
33. Danthonia spicata	x	x	x	x	x	x
34. Sphenopholis intermedia	x	x	x	x	x	x
35. S. nitida	x	x	x	x	x	x
36. S. obtusata	x	x	x	x	x	x
37. S. o. var. pubescens		x			x	x
38. Agrostis albea	x	x	x	x	x	x
39. A. hiemalis	x	x	x	x	x	x
40. A. perennans	x	x	x	x	x	x
41. Alopecurus ramosus	x	x		x	x	x
42. Aristida oligantha	x	x	x	x	x	x

TABLE III—(Continued)

Species	P	L	TP	L	U	LW
43. A. purpurascens	x	x	x	x		x
44. Brachyelytrum erectum	x	x	x	x	x	x
45. Cinna arundinacea	x	x	x	x	x	x
46. Muhlenbergia frondosa	x	x	x	x	x	x
47. M. schreberi	x	x	x	x	x	x
48. M. sylvatica	x	x	x	x	x	x
49. M. s. var. attenuata			x	x	x	x
50. M. tenuiflora	x	x	x	x	x	x
51. Sporobolus neglectus	x	x	x	x	x	x
52. S. vaginaeflorus	x	x	x	x	x	x
53. Bouteloua curtipendula	x	x	x	x	x	x
54. Eleusine indica	x	x	x	x	x	x
55. Leersia oryzoides	x	x	x	x	x	x
56. L. virginica	x	x	x	x	x	x
57. Zizania aquatica v. interior	x	x	x	x		
58. Cenchrus longispinus	x	x	x	x	x	x
59. Digitaria filiformis	x	x	x	x	x	x
60. D. ischaemum	x	x	x	x	x	x
61. D. sanguinalis	x	x	x	x	x	x
62. Echinochloa crusgalli	x	x	x	x	x	x
63. E. walteri	x	x				
64. E. w. var. laevigata	x	x		x	x	x
65. Panicum agrostoides	x	x	x	x	x	x
66. P. capillare	x	x	x	x	x	x
67. P. clandestinum	x	x	x	x	x	x
68. P. depauperatum	x	x		x	x	
69. P. dichotomiflorum	x	x	x	x	x	x
70. P. dichotomum	x	x	x	x	x	
71. P. huachucae	x	x	x	x	x	x
72. P. lindheimeri	x	x	x	x	x	x
73. P. linearifolium	x	x	x	x	x	x
74. P. l. var. werneri	x	x		x	x	
75. P. philadelphicum	x	x	x	x	x	x
76. P. scribnerianum	x	x	x	x	x	x
77. P. tennesseense	x	x	x	x	x	x
78. P. villosissimum	x	x	x			
79. P. virgatum	x	x	x	x	x	x
80. Paspalum pubescens	x	x	x	x	x	x
81. Setaria italica	x	x	x	x	x	x
82. S. lutescens	x	x	x	x	x	x
83. S. viridis	x	x	x	x	x	x
84. Andropogon gerardi	x	x	x	x	x	x
85. A. scoparius	x	x	x	x	x	x
86. Sorghastrum nutans	x	x	x	x	x	x

TABLE IV

Distribution types and Group types of Extraneous Species.

Group Type	Distribution Type	Species No. of Table II	Compass Directions W	NW	N	NE	E	SE	S	SW	Botanical Areas P	L	TP	I	U	LW
I	1	106		x							1	1				
	2	59	x	x	x						1	1				
	3	12, 27, 58, 63, 71, 72, 81, 88, 110, 112, 126	x	x	x	x					11	10	5			
	4	2, 7, 15, 26, 28, 31, 33, 42, 48, 49, 64, 92	x	x	x	x	x				10	11	7	4	3	2
	5	5, 60, 101, 122, 25		x	x	x					4	5	2	1	1	
	6	13, 19, 23, 24, 73, 107		x	x	x	x				4	5	4	2	1	
II	7	44, 96, 127		x	x	x	x	x			2	3	1			
III	8	51			x	x	x				1	1				
	9	104				x	x				1	1				
	10	11, 22, 95, 114				x	x	x			1	1	1		3	
IV	11	99, 128, 131				x	x	x	x		2	3				
	12	124, 125				x	x	x	x	x	1	1		1	1	
V	13	130					x	x	x				1	1		
	14	1, 137, 139, 84					x	x	x	x				5	2	2
	15	10, 16, 129, 136	x				x	x	x	x				2	5	3
	16	133						x	x	x				1	1	1
VI	17	90	x	x				x	x	x		1	1	1	1	1

TABLE IV—(Continued)

Group Type	Distribution Type	Species No. of Table II	Compass Directions W	NW	N	NE	E	SE	S	SW	Botanical Areas P	L	TP	I	U	LW
VII	18	35, 85							x	x		1	1	1	1	1
	19	53	x	x					x	x	1	1	1			
	20	61, 65, 80	x	x						x	1	1	1	2	2	2
VIII	21	118, 120, 135	x	x	x					x	3	3	1	1	1	
	22	41, 46, 78	x	x	x	x				x	3	3	1	1	1	1
IX	23	115		x	x	x	x	x	x		1	1				
	24	38, 79, 113			x	x	x	x	x	x	3	3		1	1	1
	25	30, 36, 37, 47, 52, 62, 83, 97, 119, 132, 138	x			x	x	x	x	x	2	1	8	9	11	9
	26	21, 55	x	x			x	x	x	x			1	8	2	2
	27	4, 32, 69, 86	x	x	x	x	x			x	3	3	3	3	3	3
	28	8, 9, 14, 50, 56, 57, 89, 111	x	x	x	x	x	x			7	6	6	4	4	2
X	29	20, 54, 82, 87, 98, 105, 116, 123	x		x	x	x	x	x	x	3	5	7	8	8	4
	30	29, 45, 69, 75, 94, 102, 103, 108, 109, 117, 140, 141	x	x		x	x	x	x	x	8	10	11	12	11	11
	31	76, 77, 136	x	x	x	x	x		x	x	3	3	3	1	3	
	32	3, 6, 39, 66, 67	x	x	x	x	x	x		x	5	5	4	3	3	2
	33	43, 68, 91, 121	x	x	x	x	x	x	x		4	4	4	1	1	
XI	34	17	x	x		x	x			x	1	1	1	1	1	
XII	35	100			x	x	x	x		x			1	1	1	
	36	34			x	x	x		x	x	1	1	1	1	1	
	37	74	x	x		x	x		x	x	1	1	1	1	1	1
	38	18	x	x	x	x		x		x	1	1	1	1		1
	39	40	x	x		x			x	x					1	

AN ECOLOGICAL STUDY OF THE KLEIN WOODS, JENNINGS COUNTY, INDIANA

By Carl O. Keller

The primeval forest of Indiana was without doubt representative of some of the most magnificent sections of the great eastern deciduous region. In a previous paper (9) we described briefly the fate of our hardwoods, and pointed out that only small tracts of comparatively undisturbed stands remain for observation. Since reports on the early forests are rather vague, and based on superficial observation rather than on quantitative data, it is somewhat difficult to gain from them a true picture of the phytosociology of these forests prior to time of settlement. Qualitative and quantitative studies of the remaining small stands referred to above, however, enable us to set up, or establish a fairly accurate norm with which to compare areas which have been disturbed, and see to what extent this disturbance has progressed. For detailed studies of a number of such stands, the reader is referred to the following literature references (1, 2, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 19).

As these remnants of the primeval forest give us a concept of what the sociology of the original forests comprised, they also clear up some existing misconceptions concerning forest types found in Indiana at the present time. Zon (21) has placed the greater part of Indiana woodlands into the oak-hickory type. The Committee on Forest Types of the Society of American Foresters (20) places the eastern "flats" area into the beech type, with beech definitely predominating. It might be reasonable to expect that an area so small as the state of Indiana, with so little variation in surface and elevation, would support a somewhat homogeneous type of vegetation, but investigations on record show that this is not the case. On the bases of these investigations Deam (4) has charted the various botanical areas of the state. McCoy (14) has shown that even on the Illinoian till plain great variation in forest composition prevails. The survey of the Klein woods not only shows the effect of various kinds of disturbance on forests in the areas compared in the present study, but also shows that in the eastern "flats" the sociology is not uniform in all stands.

The survey for this study was made in April 1943. The data have been arranged in such a way (table II) that it can readily be compared with the sixteen eastern "flats" stands studied by McCoy (14), and also with two sectors of the Guthrie Memorial Tract study made by the same writer (13).

LOCATION OF THE AREAS CONSIDERED

The eighteen forest stands referred to in this study are all located within, or adjacent to, that section of the Illinoian till plain known as the eastern "flats." This includes all of Ripley County, practically all of Jennings County, and the edges of the counties adjoining these two.

The Klein woods lies near the northwest corner of Jennings County, in Geneva Township, Sec. 8, T. 7N., R. 8E. Of the other stands considered, 2-A through 2-F, and the two sectors of the Guthrie Memorial Tract are also located in Jennings County. 2-G through 2-J are in the western part of Jefferson County. 2-K is in the southeastern part of Jackson County. 2-L through 2-O are in Ripley County, and 2-P is in the southeastern part of Franklin County. All stands lie within the boundary of the eastern "flats." area except 2-H, 2-I, 2-J, and 2-K.

GEOLOGY AND PHYSIOGRAPHY OF JENNINGS COUNTY

The physiography of Jennings County is that of the till plains section of the Central Lowland province of the United States (11). Locally it is part of the Muscatatuck Regional Slope, a structural upland plain developed on Silurian and Devonian formations. The elevation ranges from 535-767 feet, with an average of 710 feet. The land slopes generally to the west and southwest at a rate of 18 feet to the mile. This is somewhat less than the slope of the underlying strata of bedrock. The bedrock consists mainly of limestone which is overlain by a stratum of dark oil shale in the western part of the county. The pre-glacial relief has been somewhat evened by a thin layer of Illinoian drift ranging in depth up to 100 feet. On the divides this old drift surface is almost featureless.

According to the 1940 soil survey report (10), the normally developed soils of Jennings County are leached and belong to the gray-brown podzolic soils group (12). This kind of soil is generally found under forest covers in a humid, temperate climate. On the flat, poorly drained forest land, which is characteristic of most of the county, soil development has been extreme, and planosols, or "claypan" soils have been formed. These planosols owe their character primarily to the influences of relief and time. Climate and native vegetation are negligible factors in their formation.

The soil type found to be most extensive in Jennings County is Clermont silt loam. This occurs on the flattest central parts of the main divides, and is separated from the open drainage ways by almost continuous strips of Avonburg silt loam. The soil is of a light gray color, and has a definite acid reaction. Due to its flat relief and its impervious lower horizons, drainage is very poor. Because of this, it is generally unsuitable for the growth of crops. By extensive treatment it could be improved, but in many cases the cost of treatment would exceed the market value of the unimproved land (10).

The soil of the Klein woods appears to be somewhat more sandy than that in other parts of the county, showing streaks of yellowish, sandy clay.

CLIMATE AND RAINFALL

The climate of this area is continental in nature, with hot summers and moderately cold winters. The rainfall is fairly evenly distributed throughout the year. Occasional dry periods occur in late summer and autumn. The average frost-free season runs from April 26 to October 14, a period of 171 days. Records show, however, that frost has come as early as September 16, and as late as May 26. The following data, taken from the records of the U. S. Weather Bureau station at Butlerville, give a summary of the temperature and precipitation in Jennings County over a period of several years.

TEMPERATURE

(Degrees Fahrenheit)

	Mean	Maximum	Minimum
Winter	32.7°	73°	–26°
Spring	53.2°	98°	2°
Summer	74.1°	109°	35°
Fall	57.1°	103°	1°

PRECIPITATION

	Mean	Total for Driest Year	Total for Wettest Year	Snow Av. Depth
Winter	11.30	4.83	13.54	19.6
Spring	13.68	5.13	15.69	4.8
Summer	12.18	11.68	13.38	0
Fall	10.31	6.11	18.75	1.1

Figures represent inches of precipitation.

AGRICULTURAL HISTORY

The decline of the forests in Jennings County began during the early days of settlement. Naturally, since the settlers had to get their living from the soil, the clearing of the land was their first important task. Much of the timber cut was used for building purposes, but since the need of tillable acreage was greater than the market for timber, much, also, was wasted. Lumbering soon became an important industry in this area, and continued to be until a few years ago, when the supply of good timber became almost depleted.

Commercial agriculture also developed rapidly and reached its peak between 1879 and 1919. Since 1919 the production of corn, wheat, and oats decreased rapidly. In 1934 the production of corn amounted to about 66% of that reported for 1919, and wheat had dropped to 50%. There has been an increase in the production of soybeans and vegetables, but this increase does not begin to compare with the decrease in acreage of cereal crops.

Assessors' reports for 1926-33 classify 25% of this area "not in farms." Nearly 30 per cent is rough pasture, timber, and waste land, and 10 per cent is idle crop land. Sixty-five per cent of Jennings County has little agricultural use except as pasture land of limited value. Only 25% is actually in harvested crops.

According to the Soil Survey of 1940 (10), about 16% of the county was then woodland. Nearly all of the merchantable timber, which originally was very abundant, had been cut. A few of the wooded areas are classified as forests by the state.

Up to now, little has been done to reforest lands that have been cleared and later abandoned for agricultural use. It is encouraging to note, however, that interest in reforestation of such areas in Indiana is growing, and that definite steps in this direction are being taken.

METHODS

This study is based on 50 100-square-meter quadrats, run in two parallel sectors, 10 meters apart. A skip of 10 meters was left between each quadrat. The laying out was done with a line looped at 10-meter intervals, as described in our previous studies (9, 19).

Wooden calipers were used to take the DBH. measurements. All stems over one inch in diameter were measured and recorded. All stems measuring less than one inch DBH. were also counted if they were one meter or more in height. Although these were not figured into the basal area percentages, they were included to show what is taking place in the dynamics of reproduction. In table I the results of the survey are presented as representative of a stand in order to give an over-all picture of the sociology of the woods. In table II the findings are presented in units of 20 quadrats each in order to afford a more simple comparison with the "flats" areas studied by McCoy (14). Table II also includes two sectors of McCoy's survey of the Guthrie Memorial Tract (13) which was also referred to by way of comparison.

A comparison of frequency index and density of leading species found in the different areas was also made. These are shown in tables III, IV, and V. A summary description of all areas considered is presented in table VI.

The figures in columns 2, 3, and 8 of table VI represent the tree species listed with corresponding numbers at the head of the table. The basal area figures in column 4 are estimates, arrived at by taking an average DBH. figure for all the trees in each size class, rather than determining the basal area of all trees involved. Although this method allows for a certain percentage of error, it is not likely that it would make any change in the relative status of any sector, since estimates for all the sector were made in the same way.

OBSERVATIONS

In the Klein woods survey, there were 30 different woody species found. Of these, 14 are tall trees, 6 small trees, 3 shrubs, and 7 lianas. The dominant tall tree species, in decreasing order of importance, as shown by basal area percentages are: *Quercus palustris*, 27.05%; *Q. alba*, 21.69%; *Fagus grandifolia*, 21.61%; and *Acer rubrum*, 6.24%. On the basis of frequency, the following order would prevail: *Fagus grandifolia*, 98%; *Acer rubrum*, 76%; *Nyssa sylvatica*, 74%; *Liquidambar styraciflua*, 70%; and *Ulmus thomasii*, 56%. These are the only species in the large tree class showing a frequency of more than 38%. The higher frequencies found among the other classes were: *Smilax rotundifolia*, 80%; *Sassafras variifolium*, 54%; *Rhus toxicodendron*, 54%; and *Prunus serotina*, 48% (table I).

Among the young trees below one inch DBH., *Fagus grandifolia* showed the highest abundance, being followed by *Fraxinus americana* and *Acer saccharum* (tables IV and VI).

In six of the areas presented in McCoy's study of 1939 (14), *Fagus* alone represented 50%, or more, of the total basal area. In three other areas it showed the highest percentage, and ran second high in three areas (table VI). In the Guthrie Memorial Tract (13) *Fagus* was second high in the two sectors presented (table VI). Other trees with high basal area percentages in the "flats" sectors are: *Quercus palustris, Acer rubrum, Liquidambar styraciflua,* and *Quercus alba.*

The highest frequencies shown in McCoy's "flats" studies are as follows: *Fagus grandifolia,* 71.9%; *Liquidambar styraciflua,* 55.6%; *Nyssa sylvatica,* 46.3%; *Acer rubrum,* 43.8%; *Ulmus thomasii,* 36.2%; *Quercus alba,* 33.1%; and *Acer saccharum,* 30.6%.

In the Guthrie Tract as a whole the frequencies run as follows: *Acer rubrum,* 90%; *Carya ovata,* 83%; *Liquidambar styraciflua,* 74%; *Sassafras variifolium,* 70%; *Fagus grandifolia,* 66%; *Nyssa sylvatica,* 65%; *Ulmus americana,* 56%; *Carpinus caroliniana,* 45%; *Quercus palustris,* 39%; and *Fraxinus lanceolata,* 35%.

In the 50 quadrats of the Klein woods survey there were 439 stems above one inch DBH. Of these, 135 were *Fagus grandifolia,* 89 *Nyssa sylvatica,* and 59 *Acer rubrum.* This is an average of about 172 for each 20 quadrats. The other areas range from 71 to 586 per 20 quadrats. In the Guthrie Tract each sector had from 511 to 518 stems in this class, but there were no stems above 25 inches DBH.

In the count of stems below one inch DBH., *Fagus grandifolia* leads in the Klein woods with a total of 500. *Fraxinus americana* is second, with 277, and *Acer rubrum* is represented by 224 stems. In all, 1837 small stems were counted in the 50 quadrats, making an average of 612 for each 20 quadrats. In the Guthrie Tract the number ran from 498 to 679. In the other sectors a great deal of variation appeared, the lowest being 4 stems, and the highest 1263.

From the data assembled, no basis can be found for classifying the Klein woods, or the eastern "flats" forests as a whole, as a beech-maple forest as listed (type 57) by the American Society of Foresters (20). Viewing this area as a unit, we find various stages of transition between the flood-plain type of forest and the mature mixed-mesophytic forest which is quite common in this part of Indiana.

DISCUSSION

In comparing the Klein woods with other areas in the eastern lobe of the "flats," it is quite apparent that it comes nearer than any other to being a typical remnant of the original forest in this part of the state. Only five other stands have a comparable basal area coverage. Two of these slightly exceed that of the Klein woods, but due to pasturing and cutting, other factors do not compare so well (table VI). Only seven other areas have a comparable number of stems below one inch DBH. In some sectors this number runs very low, indicating that reproduction is being greatly reduced by pasturing and other disturbances. The average number of stems above one inch DBH. per sector in the Klein woods is about 172. In the Guthrie Tract the stems in this class number about 500 per sector. In six of the other sectors compared they also ran considerably over 200 stems, indicating a lack of maturity, or the result of some disturbance in the past.

The number of very large trees found also tells a significant story. In the 50 quadrats of the Klein woods there were 22 trees with DBH. measurements above 25 inches. This is an average of 8.8 per sector. In the Guthrie Tract there were no 25-inch trees. In the sixteen other sectors there were 43 such large trees found, making an average of 2.69 per sector. Five of these sectors, also, had no stems 25 inches or more in diameter.

On the basis of frequency, we should classify the Klein woods as a Fagus-Acer rubrum-Nyssa-Liquidambar-Fraxinus americana association. Considerable modification in drainage and soil conditions would have to take place before the true Acer-Fagus climax could be reached. The Guthrie Tract would fall into the Acer rubrum-Fagus-Carya ovata-Quercus palustris type of forest, with a number of other species showing a relatively high frequency, but since a number of abnormalities occur in the various factors involved in standards of comparison, it becomes obvious that this is not virgin forest, but second growth timber in a fairly mature stage of secondary succession. Factors indicating this are, the high frequency of Sassafras (70%), the greater number of species with high frequencies, and the greater number of stems above one inch DBH. The other areas compared show considerable variation, as may be seen from the frequency column in table VI, but *Acer rubrum* or

Acer saccharum and *Fagus grandifolia* are very prominent in most of them. In three of the stands, Fagus was the only genus with a frequency of more than 65%.

In most of these areas a direct correlation can be drawn between the soil conditions and the dominants growing there. Although the structure of the soil is largely uniform throughout, there are differences in drainage conditions. The high abundance of *Acer rubrum* in most of the stands and the scarcity or complete absence of *A. saccharum* shows that in most places the drainage is poor. *Acer saccharum* was prominent in only three areas, and these showed evidences of improved drainage.

Cain (3) points out that density, usually estimated under the name of abundance, should be distinguished clearly from dominance, the area or space covered by the plants. No attempt was made in this study to estimate the crown coverage of the various species, but a study of basal areas yielded some interesting figures. The oaks in the Klein woods cover more basal area than any other species. *Quercus palustris* and *Q. alba* control almost 50% of the total. In the Guthrie Tract, *Acer rubrum,* and *Fagus grandifolia* have the highest basal areas. In the other sectors, Fagus runs highest in most cases, being followed by *Liquidambar,* Acer, and Quercus. The Acer referred to is *A. rubrum* in most stands, but in the drier sites, *A. saccharum* takes its place.

In the "flats area we get a kaleidoscopic view of vegetation in various stages of succession, and, as these surveys and the agricultural history of Jennings County show, these stages represent various phases in Nature's fight to restore what man has, through ignorance and greed, destroyed. Most of the land in this region has, at some time or other, been stripped of its natural vegetation in an attempt to turn it into something for which it was never adapted. The result has been a struggling existence for many of its inhabitants, and a wasted opportunity to produce for coming generations that material, the shortage of which is becoming more and more critical, lumber.

SUMMARY

1. This study is the result of a survey of the Klein woods, located in Jennings County, Indiana, and a comparison of the findings with those from 18 other sectors previously surveyed in this general area. All sectors are located within the so-called "flats" region of

the Illinois Till Plain. The study is based on frequency, abundance, and basal area data derived from fifty 100-square-meter quadrats in the Klein woods, and twenty 100-square-meter quadrats in each of the other forests.

2. The findings show that the forests studied are not merely parts of a homogeneous association, but they represent various transitional stages.

3. In the Klein woods survey, 30 different woody species were found. Of these, 14 are tall trees, 6 small trees, 3 shrubs, and 7 lianas.

4. *Fagus grandifolia, Nyssa sylvatica,* and *Acer. rubrum* make up more than 50% of all stems above one inch DBH. in the Klein woods. *Quercus palustris* and *Q. alba* constitute almost 50% of the basal area. *Fagus grandifolia* is, with few exceptions, very prominent in the other areas considered, but a marked degree of difference was found in the general sociology of the various areas.

5. The dominant tall tree species, from the standpoint of frequency, are: *Fagus grandifolia,* 98%; *Acer rubrum,* 76%; *Nyssa sylvatica,* 74%; *Liquidambar styraciflua,* 70%; *Fraxinus americana,* 70%; and *Ulmus thomasii,* 54%. Considering the basal area percentages, the following order prevails: *Quercus palustris,* 27.05%; *Q. alba,* 21.69%; *Fagus grandifolia,* 21.61%; *Liquidambar styraciflua,* 9.5%; *Nyssa sylvatica,* 6.58%; and *Acer rubrum,* 6.24%.

6. In the count of stems below one inch DBH., *Fagus grandifolia* leads the large tree class with a total of 500. *Fraxinus america* is represented by 277 stems, and *Acer rubrum* by 224. Beech and maple are not consistently prominent among the small stems of the other areas with which this woods was compared.

7. Considering the existing sociology of the forests of the "flats" region, no basis can be found for classifying the area as a whole, or any part of it, as beech-maple forest, as listed (type 57) by the Society of American Foresters. Each represents a transition type of the mixed-mesophytic forest in various stages of transition from the near flood-plain type of forest to that approaching climax.

8. The study also shows the result of disturbance in the various stands, and points out the advisability of an intensive reforestation program for the "flats" area.

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TABLE I

Size-classes, basal area percentages, and frequency index of various species in 50 quadrats of the Klein woods.

Species	Below 1″	1″	2″	3-5″	6-10″	11-15″	16-20″	21-25″	26-30″	31-35″	36-40″	41-45″	Total Stems above 1″	Basal Area in sq. ft.	Basal Area Percentage	quency Index
Acer rubrum	224	29	3	8	12	4	2		1				59	15.55	6.24	76
Asimina triloba	2															2
Carpinus caroliniana	2	2		1									3	.10	.04	8
Carya laciniosa	12															16
C. ovata	19			3	1				1				5	3.83	1.44	30
Celastrus scandens	3															2
Cornus florida	37	5		1									6	.08	.03	22
Fagus grandifolia	500	68	22	3	3	18	16	5					135	57.37	21.61	98
Fraxinus americana	227	2				1							3	.93	.35	70
F. biltmoreana	1															2
Lindera benzoin	63	1											1	.005	.001	24
Liquidambar styraciflua	51	3		1	17	12	3	1					37	25.23	9.50	70
Liriodendron tulipifera	23	2	2					1					5	2.69	1.01	30
Morus rubra	3															6
Nyssa sylvatica	78	20	19	33	14		1		2				89	17.46	6.58	74
Ostrya virginiana	2															4
Prunus serotina	46	9	1										10	.07	.03	48
Quercus alba	6	1			2	4	5	4	2		2	1	21	57.58	21.69	38
Q. borealis var. maxima	1					1	3	1					5	8.43	3.18	8

TABLE I—(Continued)

Species	Below 1″	1″	2″	3-5″	6-10″	11-15″	16-20″	21-25″	26-30″	31-35″	36-40″	41-45″	Total Stems above 1″	Basal Area in sq. ft.	Basal Area Percentage	quency Index
Q. palustris	1					4	5	5	7	2			23	71.80	27.05	38
Q. prinus	9	1				1					1		3	.93	.35	14
Rhus toxicodendron	388															54
Ribes spp.	24															4
Rubus occidentalis	38															6
Sambucus canadensis	18															16
Smilax hispida	1															2
Smilax rotundifolia	569															80
Sassafras albidum	54	4			1	1	1						7	1.39	.52	54
Ulmus thomasii	145	14		8	5	1							28	1.01	.38	56
Vitis spp.	7															8

TABLE II

Size-classes of leading tree species in two sectors of the Klein woods and two sectors of the Guthrie Memorial Tract arranged in units of 20 quadrats each for comparison with McCoy's Illinois Till Plain studies.

	Sector A—Klein						Sector C—Klein						Sector B—Guthrie					Sector D—Guthrie				
Species	Below 1"	1-5"	6-10"	11-15"	16-25"	Over 25"	Below 1"	1-5"	6-10"	11-15"	16-25"	Over 25"	Below 1"	1-5"	6-10"	11-15"	16-25"	Below 1"	1-5"	6-10"	11-15"	16-25"
Acer rubrum	26	9	6	2		1	149	15	5	2	2		58	97	2	3		69	112	7	1	
Carya laciniosa	8						2															
C. ovata	11						8	3	1		1		31	15	1	1		15	24			
Fagus grandifolia	131	43	1	7	6		214	44		4	6		11	40	7	1		6	15	2	2	
Fraxinus americana	90						113	1														
F. lanceolata														5				2	5			
Liquidambar styraciflua	20	1	4	4	2		13	2	10	6			3	63	11	2		14	35	6	2	
Liriodendron tulipifera	5	3					8				1		25	60	3	1	1	15	30		1	
Nyssa sylvatica	38	43	5			1	38	26	7		1	1	12	20	1			19	17	2	1	
Quercus alba	4	1	1	2	7	2	2		1	2	2	3				1	2		4			1
Q. bicolor													2	1	1							
Q. borealis var. maxima	1			1	4													1				
Q. palustris	1			2	4	2				2	4	5	2	34	1			2	19			
Q. Prinus	5	1				1	3											10	3			
Ulmus americana													5	11	2			14	21	4		
Ulmus thomasii	29	1					76	15	1					3	1			1	12	2	1	

TABLE III

Frequency index of leading large tree species in the Klein woods compared with other areas in the eastern "flats."

Species	Klein Woods	2-A	2-B	2-C	2-D	2-E	2-F	2-G	2-H	2-I	2-J	2-K	2-L	2-M	2-N	2-O	2-P	Guthrie Memorial
Acer rubrum	76	95		15		65	100	40	65	40	45	85	35	50	15	50		90
A. saccharum			95		90	65	10	40			95						95	5
Carya laciniosa	16	20	10		5			5	15	25		10						
C. ovata	30	35	20	20	25	95	85	90	25	15	50	35	10	25	40	70	25	83
Fagus grandifolia	98		95	90	80	95	65	95	95		70	40	60	95	95	100	75	66
Fraxinus americana	70		10			35		10							20	80	65	1
F. biltmoreana	2		60	5	25	5		15	25		65							
F. lanceolata			75		30	85	35				35		5					35
Liquidambar styraciflua	70	90	40	45	30	60	95	100	65	100		85	5	30	60	80	5	74
Liriodendron tulipifera	30		25		20	30	90	60	30		5			5	25	15	30	66
Nyssa sylvatica	74	65	10	5	10	40	95	40	70	100	20	70	20	30	40	55	75	65
Quercus alba	38	20	5			80	15	45	55	65	65	55	25	20	10	35	35	25
Q. borealis var. maxima	8				5	55	20	10	35	15	15	55	10	10	5	25	20	12
Q. palustris	38	90					50	5	15	35		50	40	20				39
Ulmus americana			25				65	5			10				10	70	10	56
U. thomasii	56	100		20	45	60	45	70	70	25		30	10	20	15			29

TABLE IV

Density of stems below 1 inch DHB of leading large tree species in twenty-one 20-quadrat sectors of the eastern lobe of the "flats" area.

Species	1-A	1-C	2-A	2-B	2-C	2-D	2-E	2-F	2-G	2-H	2-I	2-J	2-K	2-L	2-M	2-N	2-O	2-P	3-B	3-D
Acer rubrum	26	149	202				2	91	19	19	1	7	284		6	1	16		58	69
A. saccharum				584		96	31		30			121						227		
Carya laciniosa	8	2	6	3					1	4			10							
C. ovata	11	8	16	5		14	113	24	76	8		10	11	2		36	43	4	31	15
Fagus grandifolia	131	214		153		77	73	6	305	163		27			12	37	70	22	11	13
Fraxinus americana	90	113		1			15		2							6	38	19		
F. biltmoreana	1			50	1	17	1		3	6		16								
F. lanceolata				35		15	95	3				12		1						2
Liquidambar styraciflua	20	13	16	72	5	9	4	32	421	12	9		115			26	61		3	14
Liriodendron tulipifera	5	8		18			17	33	10	8						1			25	15
Nyssa sylvatica	38	38	29	1			13	45	7	35	34	4	77			8	36	56	12	19
Quercus alba	4	2		1			48		14	17		9	30				2			
Q. borealis var. maxima	1						20	2	2	8		1	16				3			1
Q. palustris	1		9					7		1			14						2	2
Ulmus americana				9				19									39		5	9
U. thomasii	29	76	210		5	3	18	5	35	12	5		2			3				1

TABLE V

Density of stems 1 inch DBH and over of the leading large tree species in twenty-one 20-quadrat sectors of the eastern lobe of the "flats area.

Species	1-A	1-C	2-A	2-B	2-C	2-D	2-E	2-F	2-G	2-H	2-I	2-J	2-K	2-L	2-M	2-N	2-O	2-P	3-B	3-D
Acer rubrum	18	24	132		3		22	117	9	43	13	5	11	11	22	6	12		102	120
A. saccharinum				64		64	10	2	1			106						85		
Carya glabra							1				3	37						8		
C. laciniosa						1					7		2							
C. ovata		5	7	3	8		31	19	41		3	13	2	2	9	10	8	2	17	24
Fagus grandifolia	57	54		29	53	32	36	18	65	41		41	13	24	58	37	42	23	48	19
Fraxinus americana		1		2			1									2	10	9		
F. biltmoreana				4		22				2		4								
F. lanceolata				7		14		7											5	5
Liquidambar styraciflua	11	18	119	5	14	4	16	109	134	15	240		19	1	8	22	15	1	76	43
Liriodendron tulipifera	3	1		16		5	2	65	28	2		2			2	8	3	11	65	31
Nyssa sylvatica	49	35	66	1	1	2	14	36	3	21	222	4	13	5	7	8	17	36	21	20
Quercus alba	13	8	7				3	3	11	8	42	32	44	14	4	3	7	17	3	5
Q. borealis var. maxima	5					1		3	1	3	4	4	12	2	3	1	6	5		
Q. palustris	8	11	116					36	1	2	7		18	10	8				35	19
Ulmus americana				1				17	1			3				3	26	2	13	25
U. thomasii	1	16	109		2	12	1	11	28	10	4		6	2	8	1			4	15

TABLE VI

Summary comparison of all stands.

1—Fagus grandifolia
2—Acer rubrum
3—Acer saccharum
4—Fraxinus americana
5—Fraxinus lanceolata
6—Liquidambar styraciflua
7—Carya ovata
8—Nyssa sylvatica
9—Quercus alba
10—Quercus palustris
11—Ulmus thomasii
12—Liriodendron tulipifera
13—Carya glabra
14—Ulmus americana

Numbers of species above correspond with those in columns 2, 3, and 8 below.

Sector	Leading trees below 1″ dbh.	Leading trees 1″ or over (rated on basal area)	Est. basal area of all stems above 1″ dbh. (sq. ft.)	Total Stems Below 1″ dbh.	Total Stems 1″ or over	Stems Above 25″ dbh.	Species with Frequencies Above 65	Number of Species Represented	Disturbance
1-A	1, 4	9, 10	86.21	896	179	7	1, 8, 4, 6, 2	21	None
1-B	1, 2	10, 9	98.45	1,192	181	9	1, 8, 2	19	None
2-A	11, 2	10	30.68	794	628		11, 2, 6, 10	12	None
2-B	3, 1	1	49.25	1,263	216	5	1, 3, 5	15	None
2-C	6, 11	1	77.86	14	81	1	1	7	Severe pasturing
2-D	3, 1	1	34.25	361	170	3	3, 1	12	Very little
2-E	7, 5	2, 6	27.26	811	168		1, 7, 5, 9	13	None
2-F	2, 8	6, 2	16.40	774	586		2, 6, 8, 12, 7	17	Some years ago
2-G	6, 1	1	50.82	1,046	366	2	6, 1, 7, 11	17	Very little
2-H	1	1, 6	53.29	550	187	3	1, 8, 11	17	Very little
2-I	8	6	45.08	84	567		6, 8	12	Cattle range
2-J	3	9, 1, 3	43.32	389	373	1	3, 13, 1	18	None
2-K	2, 6	1	32.14	746	172		2, 6, 8	12	Slight cutting
2-L	7	10, 1	80.87	4	71	6	None	10	Pasturing and cutting
2-M	1	1, 10	62.62	20	135	2	1	11	Cutting years ago
2-N	1, 7	1	102.90	159	121	6	1	13	Pasturing and cutting
2-O	1, 6	9, 1	98.26	537	147	10	1, 6, 4, 7	11	Some recent cutting
2-P	3	1, 8	76.43	723	364	4	2, 7, 12, 1	15	Cutting years ago
3-B	2, 7	6, 2, 12, 9	29.04	498	511		2, 7, 1, 6, 12	19	Cutting years ago
3-D	2, 8	2, 6, 1, 9	25.15	679	518		2, 7, 14, 8, 12, 6, 1	19	Cutting years ago

A STUDY OF BACTERIA FOUND IN THE DISTRIBUTION SYSTEM OF A WATER PLANT

By MABEL GRACE MORRIS

One of the basic bacteriological findings used in helping to determine the quality and safeness of drinking water is the agar plate count. Raw water samples show the kind of water entering the plant and are a fair indicator of the treatment that will be needed. Plate counts of water samples taken at various places in the plant, such as settling basins or point of chlorination, show the effectiveness of the various treatment. Water leaving the plant is termed plant effluent, and results on this water are of primary concern. Its count should be very low, such as 1-8 per ml, if the water has been successfully treated.

It is also desirable to obtain plate counts on water samples throughout the distribution system, in order to know in what bacterial condition the consumer is actually receiving the water. It might be presumed that if the effluent samples show low counts, these tap samples would likewise show low counts. The writer found, however, that some tap samples in a certain distribution system often produced very high agar plate counts, amounting to hundreds per ml.

The following general observations, concerning these bacteria, were noted:

1. Nutrient agar plates incubated at 37° C. for 24 hours showed such very small colonies that it was questionable whether they were true colonies. However, further incubation showed that they were definite colonies.
2. If the additional incubation happened to be at 20° C., the colonies showed a light orange pigment.
3. There was a tendency for the high counts to be present in taps farther away from the center of the distribution system.
4. There was no consistency as to whether or not there was residual chlorine present in these samples showing high counts.
5. Several particular tap samples were generally responsible for all the high counts in the distribution system, although the counts on these samples were not consistent from day to day.

Wilson (21), in a study on the bacteriology of water pipes, states that the most efficiently operated water plants have bacteria present in the water, as many bacteria as are able to survive the dosage of chlorine lethal for coliform organisms. He further states that, although bacteria may be unable to flourish in a certain environment, they are able to survive there in an inactive state for an indefinite period and multiplication will take place rapidly when the environment is more favorable. Charlton (4), in his work on chlorine-resistance of non-sporeforming bacteria in chlorinated water supplies, encountered pigmented, Gram-negative rods which he assigned to Pseudomonas and Flavobacterium. He found that these bacteria possessed a definitely greater chlorine tolerance than intestinal rod forms.

The report of Levine and co-workers (13) shows the types of non-sporeforming organisms surviving chlorination to include members of the genera Flavobacterium, Micrococcus, Pseudomonas and Aerobacter. Likewise, Shannon (17) found a few Gram-negative yellow-pigmented bacteria belonging to the genus Flavobacterium in his work on samples from the distribution system. He encountered these pigmented bacteria chiefly on plates incubated at 20° C. Bender (1), in his study of microorganisms surviving water chlorination, placed these chromogenic organisms producing water-insoluble pigment in the genus Flavobacterium, and those producing water-soluble pigments in the Pseudomonas group.

Deutschlander (7) suggested that "old mains become coated with inorganic and organic deposits, and the bacteria adhering to these encrustations thrive and multiply. In water not sufficiently chlorinated, there is first a decrease in bacteria due to the sterilizing action of chlorine, but as soon as the chlorine has been utilized the bacteria increase. The residual chlorine progressively diminishes in the mains farther away from the pumping station, so that saprophytes are not prevented from multiplying."

PURPOSE OF THE STUDY

Since other workers have encountered similar high bacterial counts in distribution systems, it is evident that this is not entirely a local problem. An extensive and thorough study of the predominating bacteria found in the tap samples should result in showing both favorable and unfavorable conditions for the growth and multiplication of these bacteria. Although most workers, in their studies on bacteria in chlorinated water supplies, have made identification only to genus, additional identification to species would be most desirable. All of this knowledge should be beneficial to both the bacteriologist and the person responsible for the effective treatment of water.

EXPERIMENTAL RESULTS

The following experiments were carried out on the organisms isolated in this study:

1. Effect of incubation time and temperature on growth.
2. Growth on different culture media.
3. Microscopic characters.
4. Selection of satisfactory medium for growth.
5. Relationship of season to number of bacteria.
6. Presence of the organism in other parts of the water system.
7. Relationship of coliforms to the pigmented organism.
8. Starch hydrolysis.
9. Study of central swellings in the rod forms.
10. Pigment production.
11. Length of cell in relation to age and kind of culture medium.
12. Relationship of morphological changes to time.
13. Effect of hydrogen-ion concentration.
14. Effect of soluble starch concentration.
15. Effect of lactose concentration.
16. Nature of the internal granules in the cell.
17. Cell variation.
18. Characterization and identification.

1. Effect of Incubation Time and Temperature on Growth

Tap samples which showed high counts were plated on nutrient agar. Both the temperature and period of incubation were factors affecting growth of the organism as may be seen in the following table of results.

	Temp. °C.	Time hours	Size of colonies	Pigmentation	Number of colonies	Distinctness of colonies
1.	37	24	pin-point	none	medium	indistinct
2.	37	48	pin-point	none	large	distinct
3.	37	72	very small	none	large	distinct
4.	30	24	pin-point	sl. orange	less than (1)	indistinct
5.	30	48	very small	sl. orange	less than (2)	distinct
6.	30	72	very small	orange	less than (3)	distinct
7.	20	24	no colonies visible			
8.	20	48	pin-point	sl. orange	less than (4)	indistinct
9.	20	72	very small	orange	less than (5)	distinct
10.	37	24 followed by				
	20	48	medium	orange	large	distinct

A prominent characteristic of these bacteria is the development of orange pigmentation at incubation temperatures of either 30° C. or 20° C. but none at 37. A longer period of incubation increases the size, distinctness and number of colonies as well as produces more pigmentation at the lower temperatures. Optimum time and temperature for pigmentation is incubation at 37° C. for 24 hours followed by reincubation at 20° C.

2. REACTION OF THE BACTERIA TO DIFFERENTIAL CULTURE MEDIA

Colonies were picked from plates of tap samples which showed high bacterial counts. The cultures were purified by repeated plating, and then inoculated onto the various media and incubated.

Medium	Results
Nutrient agar	light orange, filiform, fair growth, smooth, adherent
Gelatin	saucer-shaped, slow liquefaction, orange
Nutrient broth	no growth
Potato	dry, lustreless, fair growth, coral pink to red
Lactose	no gas, acid of pH 5.1 produced
Dextrose	no gas or acid produced
Salicin	no gas or acid produced
Dulcitol	no gas or acid produced
Sucrose	no gas or acid produced
Egg albumin	very slowly digested, slight orange
Loeffler's blood serum	no growth, no hemolysis
Czapek's agar	slimy, light pink, smooth, fair growth
Cellulose	no digestion, orange pigmentation along surface
Cornmeal	slimy, smooth, light pink, fair growth
Lead acetate agar	slimy, smooth, pink, fair growth, no H_2S
Glycerin asparagine agar	no growth
Litmus milk	no change
Methyl red	no acid produced
Voges-Proskauer	no acetyl methyl carbinol
Nitrate reduction	Nitrates not reduced
Brilliant green bile	no gas
Tyrosinase reaction	no darkening of medium
Rubber	no growth
Hemp	scant growth
Paraffin	no growth
Deep agar	aerobic, growth along surface and upper layer
Nutrient agar with 0.2% soluble starch	orange-pink, very slimy, spreading, abundant growth
Nutrient broth with 0.2% soluble starch	Slight turbidity, moderate sediment

Since all of the pure cultures showed identical results on differential culture media, it is likely that only one species is responsible for all these high counts on certain tap samples.

3. MICROSCOPIC CHARACTERS OF THE ORGANISM

Observations were made from various media and after various periods of incubation.

MORPHOLOGY: filamentous rods which apparently segment into short rods to coccoid forms. SIZE: filamentous rods 1.2 x 8-60 microns, rods 0.8-1.2 x 2.4-6 microns, coccus 0.3-0.6 microns. GROUPING: singly, long or short chains. GRAM'S STAIN: negative. MOTILITY: non-motile. ACID-FAST: non acid-fast. COLONY: hair-like, often granules at outer end, center of colony thicker and denser, rods have swirling effect, deep colonies lens-shaped. UNUSUAL CHARACTERISTICS: *granules,* deeply staining granules distributed throughout longer rods and usually bipolar in short rods, stain well with acetic methylene blue. *Y-forms and globular bodies,* often noted on potato cultures. *Coccoid forms,* more abundant on prolonged incubation, especially abundant on lactose media from which they continue to remain coccoid when transferred to agar slants.

A striking feature of this organism is the pleomorphism, forming filaments, rods and coccus forms. Experiment 11 gives a detailed account of how the morphology is affected by age of culture medium used. On routine microscopic observation of the organism from nutrient agar slant, the growth is so slow that it must be incubated several days, and only normal rods will be observed. Granules are generally not detected unless acetic methylene blue stain is used.

4. SELECTION OF A MORE SATISFACTORY MEDIUM THAN NUTRIENT AGAR

The bacterium was inoculated onto 6 different media and incubated at 37° C. for 24 hours followed by additional incubation at 20° C. The following results were obtained: NUTRIENT AGAR: filiform, smooth, compact, adherent, fair growth. POTATO: dry, lustreless, adherent, fair growth. LEAD ACETATE AGAR: slightly slimy, smooth, spreading, fair growth. CORNMEAL AGAR: slightly slimy, smooth, spreading, fair growth. CZAPEK'S AGAR: slightly slimy, smooth, spreading, fair growth. NUTRIENT AGAR WITH 0.2% SOLUBLE STARCH: very slimy, mucous growth, colonies spreading and much larger than those on nutrient agar; growth abundant.

Satisfactory inoculations from nutrient agar cultures are very difficult. The nutrient agar to which 0.2% soluble starch has been added shows the best growth characteristics for successful inoculations. The very slimy, spreading and mucous character of the growth on 0.2% soluble starch nutrient agar raises the question as to whether the bacterium has this quality while in the water mains. Sanborn (16), in a study of bacteria which are difficult to eliminate by the use of chlorine treatment, says that the slimy bacteria are able to resist the effects of chemicals. Perhaps this quality of sliminess may explain why this bacterium is often found in tap samples which have residual chlorine.

5. CORRELATION BETWEEN SEASONS OF THE YEAR AND HIGH BACTERIAL COUNTS

Samples from 9 taps which often showed high counts were plated twice weekly on nutrient agar plates and incubated at 37° C. for 24 hours. Counts were recorded over a period of 19 months. In the following table "o" indicates low counts and "x" indicates high counts both being based on monthly averages.

	Tap Samples								
	1	2	3	4	5	6	7	8	9
January	o	o	o	o	o	o	x	o	o
February	o	o	o	o	x	o	x	o	x
March	o	o	o	o	o	o	o	o	o
April	o	o	o	o	o	o	o	o	o
May	o	x	o	o	o	o	o	x	o
June	x	x	o	o	x	x	x	x	o
July	x	x	o	x	x	x	x	x	o
August	x	x	x	x	x	x	x	x	o
September	x	x	x	x	x	x	x	x	x
October	x	x	x	x	x	x	x	x	x
November	x	x	x	x	x	x	x	x	x
December	x	x	x	x	x	x	x	x	x
January	x	o	x	o	x	x	x	x	o
February	x	x	x	o	x	x	x	x	o
March	o	o	o	o	o	o	o	o	x
April	o	o	o	o	o	o	o	o	o
May	o	o	o	o	o	o	o	o	o
June	o	x	x	o	x	o	x	x	o
July	x	x	x	x	x	o	x	x	x

These results show that higher counts appear during the summer, autumn and early winter months with lower counts during late winter and early spring months.

6. PRESENCE OF ORANGE-PIGMENTED COLONIES IN OTHER PARTS OF THE WATER SYSTEM

Samples of raw water, plant water, plant effluent and tap samples showing low counts were plated at various time intervals on nutrient agar plates and were incubated at 37° C. for 24 hours and at 20° C. for 48 hours additional incubation. No orange-pigmented colonies were ever observed on the plates of these samples. Evidently, the bacterium is not present in the water before it reaches the distribution system. Neither is it present in all tap samples.

7. RELATIONSHIP OF COLIFORMS TO PIGMENTED ORGANISMS

Fifty samples of tap water which produced pigmented colonies on nutrient agar plates were tested for coliforms, according to "Standard Methods" for water analysis. Results showed that coliforms were not present in any of the samples tested. This indicates that chlorine may be sufficient for coliforms, yet insufficient for killing these orange-pigmented organisms. This agrees with Charlton (4) who found, in a study on chlorinated water supplies, that pigmented bacteria had a greater chlorine tolerance than coliforms.

8. STARCH HYDROLYSIS

The organisms produced extensive destruction of starch in nutrient agar containing 0.2% soluble starch. There was also complete hydrolysis of starch in potato-starch nutrient broth. The standard Fehling test indicated production of glucose. The organism is, thus, actively diastatic, breaking up starch with rapidity and reducing it to glucose.

9. STUDY OF CENTRAL SWELLINGS IN ROD FORMS

Microscopic examinations were made of bacteria from various culture media in an effort to observe the conditions under which these central swellings occur. The swellings range from an enlarged central portion of the rod to spherical bodies often up to 4 microns in diameter in rods which were only 0.8 micron wide. Few terminal swellings were noted. These globular bodies were observed on both young and old cultures on potato slants. Inoculation on potato slants were not very successful, but whenever growth was obtained some swollen bodies were always observed.

The only other medium upon which they appear is sometimes on nutrient agar which has been inoculated from 0.2% soluble-starch nutrient agar. However, repeated findings show that when inoculations are made onto either nutrient agar or 0.2% soluble-starch agar, the bulbous swellings do not appear, normal rods only being present. Inoculations from potato slants to any other culture medium failed to produce the swellings.

Gillespie and Rettger (8), in their work on variant cells of *Bacillus megatherium,* state: "Variant types such as globular bodies or filaments with bulbous swellings never produced organisms of the same type. In environments responsible for their formation, they simply increase in size up to a certain point and then remain dormant until death and autolysis ensue. When transferred to new and wholesome surroundings, variable variant cells returned to 'normal' rod forms. Cells of unusual shape seem to form in response to unfavorable environmental conditions. They were presumably simple adaptive variants and did not appear to represent stages in an orderly life cycle."

The results of this experiment agree with Gillespie and Rettger in that rod-form bacteria with globular bodies produce "normal" rod forms and in that variant types occur under certain environmental conditions.

10. PIGMENT PRODUCTION

The pigment was insoluble at room temperatures in water, alcohol and xylol. The optimum time and temperature for pigmentation was 24 hours at 37° C. followed by re-incubation at 20° C. for an additional 48 hours. The 0.2% soluble-starch agar produced good pigmentation in 24 hours at 37° C.

Pigmentation as affected by medium: organisms were incubated on each of the following media at 37° C. for 24 hours followed by re-incubation at 20° C. for 48 hours (exception being made for gelatin). Results were: on 0.2% soluble-starch nutrient agar, orange-pink pigmentation; on gelatin, orange pigment; on nutrient agar, light orange; on Czapek's agar, pale pink to colorless; on cornmeal agar, pale pink to colorless; on lead acetate agar, pink; on potato, vermillion-red.

Effect of hydrogen-ion concentrations using 0.2% soluble-starch nutrient agar the following results were obtained.

Time	pH 6.2	pH 6.6	pH 7.4
48 hrs.	orange-pink	light orange-pink	very light orange-pink
1 wk.	deep orange-pink	orange-pink	orange-pink
2 wks.	almost colorless	light orange-pink	almost colorless

Media with low pH values give greater intensity of pigment, up to 2 weeks incubation. After that time, a medium or circum-neutral reaction shows the best pigmentation.

Pigmentation as related to growth: medium of pH 6.2 incubated for 1 week shows deepest pigment as well as most abundant growth, while medium of pH 7.4 incubated for 48 hours shows lightest pigment and scant growth. Factors contributing toward good growth also increase density of pigment. Most abundant growth was produced on nutrient agar containing 5% soluble starch. Pigmentation was light orange when the nutrient medium contained no soluble starch, orange when it contained 0.2% soluble starch, orange-pink when 1% soluble starch was present, and deepest pink when 5% soluble starch was present. Charlton (4), Shannon (17), Henrici (9) and Bender (1) also observed pigmented bacteria surviving water chlorination. Their studies did not include factors affecting pigmentation.

11. LENGTH OF CELL IN RELATION TO AGE AND KIND OF MEDIUM USED

The organism was inoculated onto 10 different media and microscopic examination made at certain time intervals. Longer filamentous rods seem to occur during the growth period while shorter rods appear afterward. Longer rods seem to develop on rich, moist media which are most favorable for growth. Shorter rods develop after longer incubation when the medium is less moist and less favorable to growth. This agrees with the results of Gillespie and Rettger (9) and those of Topley (19). The following table shows results.

Medium			Length in microns			
	30-60	20-30	10-20	6-10	1-6	coccoid
Nutrient agar						
24 hrs.		x	x	x	x	
72 hrs.		x	x	x	x	
1 wk.			x	x		
6 wks.		x	x	x		
2.5 mo.					x	
0.2% soluble starch nutrient agar						
24 hrs.	x	x	x	x	x	
72 hrs.					x	
1 wk.		x	x	x		
6 wks.				x		
0.2% soluble starch nutrient broth						
1 wk.		x	x	x		
6 wks.				x		x
2.5 mo.					x	x
Potato						
1 wk.				x	x	
6 wks.			x	x	x	
2.5 mo.					x	
Czapek's						
72 hrs.				x		
1 wk.				x		
6 wks.				x		
2.5 mo.					x	
Cellulose						
1 wk.	x	x	x			
6 wks.					x	x
2.5 mo.					x	x
Cornmeal agar						
1 wk.				x	x	
6 wks.					x	
Gelatin						
1 wk.				x	x	x
2.5 mo.						x

Medium	Length in microns					
	30-60	20-30	10-20	6-10	1-6	coccoid
Nutrient broth						
6 wks.					x	x
2.5 mo.						x
Phenol red lactose						
1 wk.			x	x		
6 wks.					x	x
2.5 mo.						x

12. RELATION OF MORPHOLOGICAL CHANGES TO TIME

The bacteria from actively growing cultures were observed microscopically at frequent intervals over a period of three days. The length and width of the rods remained constant during all periods of the first two days while toward the end of the third day the rods slightly decreased in both length and width. No coccus forms were observed. The granules in the rods were clearly observed during all periods of the examination. This bacterium seems to undergo a slow, gradual decrease in size and later, when reduced to a coccoid form, is unable to change back to a rod form, and also loses its power of reproduction. An exception to this is found in the coccus forms from lactose (exp. 17). There is, thus, no indication of a morphological time sycle.

Colien (5) made a 30-hour growth study of a yellow pigment-producing coccus. A change was observed from coccus to rods to filaments, to rods, to coccoid forms, to original form; this morphological cycle being completed in 30 hours. The present results show no evidence of a time cycle such as Colien observed. The results are more nearly similar to Topley's (19) discussion of Actinomyces, He says that the filaments occur in young cultures and later (24 hours to 3 weeks) the filaments segment into rods and coccoid forms.

13. EFFECT OF H-ION CONCENTRATION

The bacterium was inoculated on both 0.2% soluble-starch nutrient agar and 0.2% soluble starch nutrient broth of various pH values. Growth and microscopic characters were observed at different time intervals. Results show that the neutral and more acid media produce slightly better growth than those more alkaline. Media with pH 6.6 seem to be the most satisfactory for rods since the organisms remain as rods over a longer period of time than when grown on media with pH 6.2 or 7.4. On nutrient broth with 0.2% soluble starch, a reaction of pH 5.7 to 6.0 gave best results. The more acid medium produced shorter rods and coccoid forms while the circum-neutral and slightly alkaline media show longest rods. These results are at variance with the findings of Novak and Henrici (14), on a pleomorphic bacterium, wherein H-ion concentration did not affect morphology.

14. Effect of Concentration of Soluble Starch on Growth and Morphology of the Bacterium

The bacterium was inoculated onto nutrient agar with varying concentrations of soluble starch. Growth characteristics and microscopic examination at certain time intervals showed that as the amount of starch was increased (up to 5%) the amount of growth increased. The slimy character of the organism also increases with increased concentration of starch. The length of rods also increases as the concentration of starch is increased. Cultures incubated 2 weeks and then streaked on nutrient agar slants and incubated at 37° C. for 48 hours show that increased concentration of starch is followed by an increase in the amount of growth.

15. Effect of Lactose Concentration

The bacterium was inoculated into nutrient broth with amounts of lactose varying from 0 through 0.5%, 1%, 5%, to 10%. Best growth as determined by turbidity and sediment, is shown in the nutrient broth with 0.5% lactose. This also shows the longest rods and the rod condition continues for the longest period as compared with other concentrations. This partially agrees with Novak and Henrici (14) who found, in their work showing relationships between staphylococci and actinomycetes, that the inciting substance which caused the morphological transformation from the coccus to the rod form was a sugar.

16. Nature of Internal Granules in the Cells

Since the organisms were unable to grow on soluble-starch nutrient agar containing 0.3% sodium sulphate nor on similar media containing similar concentrations of sodium sulphite it was concluded that the granules are not sulphur. They also gave negative results when tested for starch with iodine.

The stain most satisfactory for microscopic observation of the granules was found to be acetic methylene blue.

The bacterium was inoculated onto 10 different media as follows: nutrient agar, nutrient agar with 0.2% soluble starch, potato, nutrient broth with 0.2% soluble starch, Czapek's agar, cornmeal agar, gelatin, lead acetate agar, and lactose agar. Observations after 24 hours and after one week show that few granules were produced on most media. But on prolonged incubation, rods show more granules and the rods ultimately become more indistinct until only packets of cocci remain. Cocci might be a more stable form produced under less favorable conditions. Coccus forms may not be able to reproduce except under very favorable conditions. Cocci, when reproduced, as from lactose, produce cocci and not rods.

17. CELL VARIATION

Bacterial rods, on certain media and after certain periods of time, show coccoid bacteria. Often, also, structureless, granular, lightly staining material is observed. Colien (5), in his work on microbic variation of coccoid bacteria, obtained variants by aging the cultures of the yellow pigment-producing coccus. Attempts were made to transform the cocci back to rods, but results were not successful. Rods would not develop, even on media upon which rods normally grow well. Koelz (12), in his work on Actinomyces, stated that the coccus form which developed from the rod form must be a stable form because it could not be transformed back to the rod condition.

Coccus forms appear on media which are not most favorable for growth and reproduction. In no case were definite rod forms obtained from the coccoid forms occurring in the finely granular and structureless lightly-staining material.

Increasing the concentration of lactose in the media transformed rods to coccus-like structureless material. Cultures grown in media in which growth was difficult also contained coccus-like forms instead of rods. Such media were: nutrient broth, nitrate peptone, egg albumin, dulcitol broth, Dunham's solution, rubber, hemp, lactose broth, and dextrose broth.

Rettger and Gillespie (15), in a study on cell morphology of *Bacillus megatherium,* found "relatively slight changes in environment are responsible for striking changes in cell form." They further state that "factors which stimulate cellular variation are apparently unfavorable to continued normal growth."

Transfers were made from lactose broth to the following media: nutrient agar, Czapek's agar, cornmeal agar, lactose broth, dulcitol broth, sucrose broth, 2% tryptose broth, salicin broth, dextrose broth, litmus milk, gelatin stab, nutrient broth, potato, cellulose, Loeffler's blood serum, citrate agar and starch agar. No growth occurred on: Czapek's cellulose, cornmeal and citrate agar. Starch was not hydrolized, neither nitrates, indol, acetyl methyl carbinol, nor acid (as indicated by methyl red) were produced. These results show that the coccus differs from the normal rod form in its reaction to culture media in the following ways: (1) starch is not hydrolized, while the rod form is actively diastatic. (2) Addition of starch to nutrient agar does not produce more favorable conditions for growth of the coccus form, while the rod form shows better growth when starch is added. (3) Good growth is obtained with the coccus form when incubated at 37° C. for 24 hours, while the rod form requires longer incubation. (4) The coccus form produces no pigment, while the rod form produces an orange pigment. Gillespie and Rettger (8), in their work on variant cells of *Bacillus megatherium,* consider the coccoid and rod forms as merely two extremes of cell length. Holman and Carson (10) question whether these changes in cell morphology are more than mere chance variation. The results in this work tend to agree with Gillespie and Rettger that unfavorable factors stimulate cellular variation. It is doubtful whether these are mere chance variations since repeated experiments on a large number of cultures show identical results.

18. IDENTIFICATION OF THE BACTERIUM

The characteristics of this organism may be summarized as follows: FILAMENTS AND RODS: 0.8 to 1.2 by 2.4 to 60 microns. In older cultures mostly short rods. Frequently Y, swollen, and coccus forms, staining irregularly, showing granules. Non-motile. Gram-negative. GELATIN STAB: orange surface growth. Very slow napiform liquefaction. AGAR COLONIES: small, circular, smooth, convex, adherent to medium, compact, orange. Deep colonies lens-shaped. AGAR SLANT: fair growth, filiform, smooth, light orange. STARCH AGAR COLONIES: large, circular, smooth, moist, spreading, slimy, orange-pink. STARCH AGAR SLANT: abundant, slimy, moist, spreading. CZAPEK'S AGAR SLANT: fair growth, light pink, slightly slimy. CORNMEAL AGAR SLANT: fair growth, light pink, slightly slimy. NUTRIENT BROTH: slight turbidity. STARCH BROTH: moderate turbidity, moderate sediment. LITMUS MILK: no change. POTATO: fair growth, coral-pink to vermillion-red, dry, lustreless. INDOL: not formed. NITRITES: not produced from nitrates. AMMONIA: not produced. ACID: from lactose. BLOOD SERUM: no growth. STARCH: hydrolyzed. HYDROGEN SULPHIDE: not formed. AEROBIC: facultative. OPTIMUM TEMPERATURE: 20-37° C. SOURCE: water in city distribution system. HABITAT: unknown.

Possibilities of identification. The following characters are similar to those of the genus Corynebacterium: uneven staining due to metachromatic granules, long slender rods, non-acid fast, pleomorphism, optimum growth under acid conditions, pigment production. Jensen (11), in his studies on saprophytic Mycobacteria and Corynebacteria describes a species which resembles this organism to some extent. *Corynebacterium michiganense* resembles this organism in the following respects: similar growth on potato, gelatin and broth; acid medium optimum, and scant growth at 37° C. The organism also shows some characteristics of *Corynebacterium nubium* which is feebly proteolytic and shows a pink growth on agar. Corynebacterium has the following characters which would exclude the present organism from inclusion in that genus: growth on paraffin, tendency for branching, angular growth ("snapping") Gram-positive, often club-shaped rods, growth on Loeffler's blood serum, optimum temperature 37° C.

The genus Actinomyces has the following characteristics which are similar to those of the present organism: pleomorphism, the organism segmenting into rods and coccoid forms, irregular staining showing "granules," pigment production, actively diastatic, not easily cultivated on artificial media, slow growth, no gas from carbohydrates, optimum temperature 13-32° C. Although no species of Actinomyces listed in Bergey's Manual (2) shows resemblance to this bacterium, the writer is impressed by many studies made on the genus which show similar results to those in the study of this organism. Novak and Henrici (14), in their work showing the relationship between staphylococci and actinomycetes, found that sugar was the inciting substance which caused morphological transformation. Koelz (12), in his work on 16 strains of Actinomyces, was unable to transform coccoid forms which developed from rod forms back to rod forms.

Actinomyces has the following characteristics which would exclude the present organism from inclusion in that genus: Gram-positive, prefers alkaline medium, branching forms, clubbed ends of radiating threads, aerial outgrowths, mycelium, reproduction by conidia, growth usually dry, tough and wrinkled.

The genus Flavobacterium has the following characteristics which are similar to those of the present organism: Gram-negative rods, aerobic, orange pigment, occurs in water, feeble power of attacking carbohydrates. Many workers, studying bacteria found in chlorinated water supplies, place many of the chromogenic bacteria in this genus. Bender (1) assigned some of the organisms containing water-soluble pigments and which survive chlorination to the genus Flavobacterium. Levin (13) included members of this genus among the bacteria of water distribution systems. Charlton (4), in his work on chlorine-tolerant bacteria in water supplies, assigned most of the pigmented, Gram-negative rod-forms to Pseudomonas and Flavobacterium.

No species listed in Bergey's Manual (2) shows great similarity to the present organism. The following two species are similar in several ways to the present organism yet insufficiently so to permit it to be classified as either of them. *Flavobacterium orchitidis* has bipolar staining and is Gram-negative. *Flavobacterium aurantiacum* produces limited orange on agar slant, reddish-orange pigment on potato, is Gram-negative and has an optimum temperature of 30° C.

In view of these considerations it appears that this organism is a new species and it is proposed to assign to it the name *Flavobacterium amylum* sp. nov.

SUMMARY

1. A pigmented bacterium, capable of withstanding chlorination lethal to coliform organisms, has been isolated from the distribution system of a city water supply. It is easily recognized by the formation of an orange pigment at low incubation temperatures. It appears predominately during summer and early winter months.

2. Samples of raw water, plant water, plant effluent and taps (generally) do not show this pigmented organism.

3. The organism is difficult to grow on ordinary media, but grows and multiplies well on media containing soluble starch.

4. Cell morphology varies from long, filamentous rods through short rods to coccoid forms. The longer rods occur during growth

periods and under most favorable conditions. Shorter rods and cell variations appear after a longer incubation period and under conditions unfavorable to normal growth.

5. There is no indication of a morphological time cycle.

6. Granules found in the rod forms stain well with acetic methylene blue and give negative tests for sulphur and starch.

7. The organism, in the normal rod form, is actively diastatic reducing starch to glucose. As the concentration of starch in the medium is increased, better growth and longer rods are observed. In the coccoid form the organism does not hydrolyze starch and addition of starch to the medium does not induce more growth.

8. Better growth and longer rods are produced on media with small concentrations of lactose.

9. Media which are slightly acid produce larger amounts of growth but also shorter rods and more coccoid forms than are found on alkaline media.

10. The organism shows a slimy characteristic on certain media and this may partially account for its resistance to chlorine.

11. Optimum conditions for pigmentation are: incubation at 37° C. for 24 hours followed by re-incubation for 48 hours at 20° C. and on media of low pH values with concentrations of soluble starch up to 5%.

12. It may be assumed that the following conditions are unfavorable to growth of the organism: tempertaure higher than 37° C., dryness, early spring months, alkaline conditions and chlorination above lethal dosage for coliforms.

13. The new name, *Flavobacterium amylum* sp. nov. is assigned to the organism.

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A COMPARATIVE STUDY OF THE BACTERIAL CONTENT OF VANILLA AND CHOCOLATE ICE CREAM FROM TWO INDIANAPOLIS PRODUCERS

By Leander C. Parker

The wide use of ice cream and its high susceptibility to bacterial contamination have stimulated many investigations to determine the extent, the nature and the cause of such contamination and the means of preventing or minimizing it. Inasmuch as the types of organisms found in ice cream are generally the same as those found in milk or cream, the methods of investigation are basically alike. These methods involve the use of agar plate cultures, direct microscopic observations and biochemical tests. The first two of these techniques were used in this study.

Breed and Brew (2) developed the direct microscopic method of counting bacteria in milk. Fabien (8) adapted this method to the microscopic examination of ice cream. Due to the high viscosity and fat content of ice cream, the film has been found to be too thick for practical use. Fay (6) described a modification of this method. He used 0.1 cc of melted ice cream together with 2 to 4 drops of water. These were mixed thoroughly and spread over the entire surface of the standard slide. This was dried and the film was then treated as described for milk.

Practically all of the work reported on the bacterial content of ice cream is based on agar plate counts. Hammer and Goss (9), in a study of the bacterial content of 54 samples of ice cream after one day's storage, obtained plate counts of from 30,000 to 190 million per cc. Fabian (4), in an analysis of 1,110 samples of ice cream from 36 plants in Michigan, obtained plate counts ranging from 1,000 to 300 million bacteria per gram. Yale (14) found an average plate count of 58,800 for store samples of ice cream from 12 producers in small cities in New York. Brown (3), in analyses of 570 samples of commercial ice cream from several Indiana cities, obtained plate counts below 30,000 in 66% of the samples and above 100,000 in 20% of the samples. Martin, Nelson and Caulfield (11) obtained plate counts of 100,000 or less in 60% of the samples from over 300 Kansas ice cream manufacturers. Kamplain (10), using the direct microscopic method along with the plate method, made a study to determine the sources of bacterial contamination as well as the extent of contamination from three outlets in Indianapolis. His results indicate that poor dispensing methods account for a considerable portion of the bacterial content of ice cream.

Work previously done has been confined chiefly to plain ice cream and sherberts and to use of the agar plate technique. The wide variation in counts which have been noted suggest that some producers are either careless or unscrupulous in their manufacturing procedures. At one time, ice cream was widely considered to be a dumping ground for undesirable milk. The manufacturers who engaged in this questionable practice depended on the power of flavoring materials to conceal the evidence of the presence of undesirable ingredients. Chocolate ice cream, because of its color and intense flavoring, is an ideal medium for concealing such adulterants.

In the light of these conditions, this study was undertaken to determine whether the bacterial content on the products of either of two Indianapolis ice cream producers offers evidence of such careless or unscrupulous practices.

PROCEDURE

Samples of vanilla ice cream and chocolate ice cream from each of two producers were collected each week in sterilized half-pint jars. These were brought to the laboratory and placed in a water bath at 45° C. for melting. The samples were agitated several times as they were being melted to facilitate the removal of air. The material was then plated in Bacto-trypto extract skim milk agar at 37° C. for 48 hours. The colonies which developed were counted under 7.5X magnification. Counts were recorded as number of organisms per cc. Fay (7) has shown that the variations inherent in the plate method overshadow any variations introduced by the air incorporated in volumetric samples. Consequently, it makes little difference whether volumetric or gravimetric samples were used.

Slides for direct microscopic counting were prepared by a slight modification of the method described by Fay (6). Three drops of sterile water and 0.05 cc of melted ice cream were placed on a clean 75 x 25 mm slide. The water and melted ice cream were mixed thoroughly, spread evenly over the entire surface of the slide and dried on a warm level surface. The dried film was immersed in xylol for 20 minutes, removed and dried of xylol. The film was then fixed by immersion in 95% alcohol for 5 minutes. After evaporation of the alcohol from the slide, it was stained in aqueous-alcoholic methylene blue, prepared as described in "Standard Methods" (1).

The stained slides were observed with a 1.8 mm oil immersion objective and 12.5X ocular. The diameter of the field was 0.146 mm. Counts were recorded as the number of organisms present in 30 fields. The factor used to convert this to the number of organisms per cc was calculated as follows:

$$F = \frac{A}{v \times 30a} = \frac{1875}{.05 \times 30 \times .0167} = 74810$$

or approximately 75,000, where "A" is area of slide in sq. mm., "a" is area of microscopic field in sq. mm., and "v" is volume of material used. This technique proved to be satisfactory when used with vanilla ice cream but was found to be wholly inadequate with chocolate ice cream. In addition to a high fat content, chocolate ice cream contains many particles which complicate the staining procedure to such an extent that methylene blue becomes useless as a stain for these slides. The similarity in size between many of these particles and bacteria eliminates the centrifuge as a means of separating them. Other simple stains reacted in the same manner as methylene blue.

The only staining procedure attempted that offered any hope of solution was one reported by Stoughton (12) in which thionin and orange G were used for the differential staining of bacteria and plant tissues. After treatment with xylol and alcohol in the usual manner, the ice cream films were (1) stained in carbol thionin for 5 minutes, (2) washed with water, (3) treated with 95% alcohol, (4) differentiated in orange G for several minutes, and (5) washed well in absolute alcohol. This procedure affected some differentiation but such bacteria as could be found on these mounts appeared to stain somewhat feebly. In addition, some particles which seemed not to be bacteria reacted with the stain.

RESULTS

Results are presented in tables I and II. They show a wide range in the number of bacteria per cc as determined by both the plate and the direct microscopic method. The lowest plate count in the case of each type of ice cream was recorded on a day which was not during the winter, and the highest count in each case was recorded on a day which was not during the summer. The counts varied in each kind of ice cream from each company from a few thousand to hundreds of thousands per cc.

Enumeration of bacteria in vanilla ice cream by the direct microscopice method shows counts that range from a few million to hundreds of millions per cc. The lowest count for each was during the summer and the highest count during the winter. These wide variations in the bacterial content indicate that some or all of the factors which lead to bacterial contamination of ice cream are highly variable and difficult to control.

At first thought, it would be expected that highest counts should come during the summer and lowest during the winter. But, after careful consideration of all conditions, it is to be noted that the volume of ice cream sold during the winter is much less than that sold during the summer. As a consequence, the two companies considered, both of which are relatively small producers, make ice cream every day during the summer, but on only two or three days each week during the winter. Such an intermittent use of equipment in winter permits the development of those types of bacteria which are the sources of equipment and utensil contamination. Also, the longer periods of holding mix and the possible re-use of material are probably important contributing factors. This interpretation agrees with the fact that staphylococci, tetrads and sarcinae were found in large numbers in the samples. These types of bacteria commonly enter milk and milk products from fat and casein residues found in crevices and seams of utensils and machinery. Diplococci were also found in large numbers. These develop rapidly in a milk product that is held, particularly when the temperature is not low. Their presence in large numbers, especially during the winter, indicates the use of milk that is not fresh.

A comparison of vanilla ice cream from company A with that from company B reveals that the plate count, by monthly averages, of the company A product was lower than that of company B for 8 of the 10 months of observation. For the entire 10-month period the average plate count for company A was 64,525 per cc and that for company B was 179,588 per cc. This is approximately a 3:1 difference. These results indicate that, from the standpoint of sanitation, the conditions surrounding the production of vanilla ice cream by company A were more desirable than those surrounding company B.

A comparison of the total number of bacteria per cc, as determined by the direct microscopic counts on samples of vanilla ice cream, shows a striking resemblance in the general trend of results. These counts are very high in December and February for company B and in December and January for company A. In general, the counts are higher during winter than during any other season. As suggested before, the intermittent use of equipment and differences in the nature of raw materials used probably account for this trend.

The total number of bacteria per cc by yearly averages, as determined by the direct microscopic count of vanilla ice cream from company A, was 79,725,000 and for company B was 104,700,000 per cc. These results further support the conclusion that, in the manufacture of vanilla ice cream, company A is more careful in the selection of its raw materials and in its manufacturing procedures than company B.

The ratio, for vanilla ice cream, of the number of groups of bacteria observed in direct microscopic counts to the number of colonies as determined by the plate counts was 189 to 1 for company A and 279 to 1 for company B. The ratio of total number of bacteria (microscopic count) to the number of colonies per cc was 1,063 to 1 for company A and 1,396 to 1 for company B. These ratios indicate that company B depends on pasteurization to control the number of viable bacteria to a greater extent than does company A. It might be argued that the mix of company B contained a smaller percentage of heat resistant bacteria than that of company A, but the occurrence of bacteria according to morphological type in the products of the two companies is too similar to justify acceptance of such an explanation. This apparent dependence of company B on pasteurization, together with the larger viable bacterial content of its product, indicates that, from a standpoint of bacterial contamination, it markets ice cream of inferior quality as compared to that of company A.

A comparison of the bacterial count of vanilla ice cream of each company with that of good market milk (table II) reveals that ice cream, as produced by each of these companies, is decidedly inferior to market milk in all points of comparison. This is especially noticeable in the case of staphylococci, a form which originates largely from unsterile utensils and equipment.

A comparison of the viable bacterial content of the chocolate ice cream of company A with that of company B, as shown by the monthly averages of plate counts (table I), reveals no marked difference in the two products. Although considerable differences are shown in some of the individual months covered, the samples from company A had higher counts for six of these months and those from company B had higher counts for the other six months. The average count for the entire year was 162,563 in the product of company A and 175,764 in that of company B. The difference is insufficient to justify any conclusion regarding the superiority of one product as compared with the other.

The viable bacterial content as shown by plate counts (table I) of vanilla ice cream from company A is generally much lower than those of chocolate ice cream from the same company. Contamination from utensils, equipment and handling probably would be approximately the same for the two flavors of ice cream from the same company. The most likely cause for such a significant difference in the viable bacterial count of the two ice creams from the same company would be the condition of the materials used. It thus seems probable that company A selected its materials, particularly milk and milk derivatives, for vanilla ice cream with more care than it did those for chocolate ice cream. This difference could be due to a more intense pasteurization of vanilla ice cream mix than of chocolate ice cream mix.

For company B these counts are generally slightly lower for chocolate ice cream than for vanilla. The small average difference in these counts could be due to variations which might be expected in the technique of counting, or in manufacturing procedures. It thus appears evident that company B does not select fresher materials for the production of vanilla ice cream than for the production of chocolate ice cream. This interpretation overlooks the possibility that company B might use milk for chocolate ice cream inferior in quality and sterility to that used for vanilla ice cream and then subject the material to a more vigorous pasteurization procedure. In such a case advantage would be taken of the intense flavoring power of chocolate powder to cover any off-flavor occasioned by such treatment. A reduction of these counts to simple proportion follows:

Company A vanilla to company A chocolate, 1:3
Company A chocolate to company B chocolate, 3:3
Company B vanilla to company B chocolate, 3:3

These results, which reveal a lower ratio of the vanilla to chocolate count for company A than for company B, support the argument that Company A uses ingredients of lower bacterial content in the manufacture of vanilla ice cream than in the manufacture of chocolate ice cream. The principle difference probably is due to the use of fresher milk and cream for vanilla ice cream mix and the older milk and cream for the chocolate ice cream mix. The results indicate that such procedures are not used by company B. The fact that company A produces milk and prepares its own ice cream mix, whereas company B buys its ice cream mix from another concern, helps to account for such differences of procedure of the two producers. Under the circumstances, company A might have left-over milk and mix and might make such use of them.

Table I also shows results of the direct microscopic counts of bacteria in samples of chocolate ice cream from each company over a seven-week period. Each of these counts indicate an extremely high degree of bacterial contamination of the samples. For company A the total number of bacteria, as shown by these counts, ranges from a low of 1,647 million to a high of 8,635 million per cc. The range for company B is practically the same, viz., 1,502 million to 8,389 million per cc. For vanilla ice cream these ranges are, respectively, 5 million to 280 million and 7 million to 340 million, for the two companies. If these counts could be shown to be reliable, they would serve as definite evidence of either careless or unscrupulous practices in the manufacture of chocolate ice cream by each of these concerns. The reliability of these counts, however, is open to serious question.

Most of the particles of solid matter in chocolate powder stain to the same extent with methylene blue as bacteria. Further, large numbers of these particles are approximately the same size as bacteria. A study of the microscopy of chocolate powder, as described by Winton (13), reveals that these particles consist of aleurone grains, cell inclusions from pigment cells, and fine particles of cellulose. In the examination of chocolate ice cream by the direct microscopic method, it was ever difficult and often impossible to distinguish these particles from bacteria. The differential staining of this material within thionin and orange G eliminated some of the difficulties due to cellulose, but lessened the intensity of staining most of the particles which appeared to be bacteria. The use of this differential stain did not reduce the uncertainties of the identification of the particles sufficiently to justify confidence in the results obtained. These counts, therefore, are probably considerably higher than those which the actual number of bacteria present would justify. Consequently, any conclusions made therefrom must be taken with reserve.

CONCLUSIONS

1. Both plate and direct microscopic counts on ice cream were generally higher during winter than in other seasons. This was possibly due to the intermittent use of equipment and longer periods of holding in winter.

2. The viable and total bacterial content of vanilla ice cream from company A is lower than that from company B. The vanilla ice cream from company A had lower ratios of (1) the number of groups and (2) the total number of bacteria to the number of agar plate colonies. This indicates that company B used milk products of higher bacterial content and pasteurized the product to a greater extent than did company A.

3. Results of plate counts indicate that company A which produces vanilla ice cream of lower bacterial content than its chocolate ice cream, selects milk and cream of better quality for the production of vanilla ice cream than it does for chocolate ice cream.

4. There is some indication that the total bacterial content of chocolate ice cream from each company is much higher than that of its vanilla ice cream. Conclusions on this point await the development of a staining procedure which will clearly differentiate bacteria from other particles of similar size and staining properties in chocolate ice cream.

ACKNOWLEDGMENT

The writer wishes to express his sincere thanks to Dr. C. M. Palmer who suggested the problem and supervised the research, and to Dr. Ray C. Friesner for his suggestions and aid.

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TABLE I

Results of plate and direct microscopic counts on vanilla and chocolate ice cream, given as monthly averages of numbers of bacteria per cc of material.

Date	Co.	Kind	Direct counts: bacteria per 1/75,000 cc								Total in millions per cc	Plate count thousands per cc
			Diplococci	Short Strep.	Long Strep.	Staph.	Isol. cocci	Rods	Sarcinae	No. gps.		
June	A	V	13	3	4	20	5	1	24	14	5.2	19
		C										249
	B	V	42	2	0	8	5	3	32	29	6.8	79
		C										160
July	A	V	115	21	2	39	19	5	22	29	16.7	46
		C										200
	B	V	59	16	4	27	7	6	50	50	10.8	52
		C										48
Aug.	A	V	298	59	55	84	66	3	64	255	52.8	61
		C										134
	B	V	362	84	91	423	24	2	39	269	71.1	249
		C										209
Sept.	A	V	172	12	35	87	22	1	97	136	30.4	122
		C										26
	B	V	216	76	43	131	24	13	19	169	36.3	113
		C										211
Oct.	A	V	104	17	0	136	4	2	52	74	23.5	133
		C										55
	B	V	157	54	7	348	5	4	200	133	57.3	274
		C										156

TABLE I—(Continued)

Date	Co.	Kind	Direct counts: bacteria per 1/75,000 cc									
			Diplococci	Short Strep.	Long Strep.	Staph.	Isol. cocci	Rods	Sarcinae	No. gps.	Total in millions per cc	Plate count thousands per cc
Nov.	A	V	94	24	110	1124	0	1	228	124	118.6	22
		C										324
	B	V	90	25	72	1184	2	2	232	115	122.4	220
		C										188
Dec.	A	V	285	121	41	1276	5	1	418	276	181.1	114
		C	5598	4935	896	9360	1941	145	23268		3458.1	269
	B	V	259	75	17	1149	3	2	977	304	185.4	638
		C	6000	1840	3368	22812	2842	245	6248		3216.6	176
Jan.	A	V	524	31	40	691	3	1	2069	552	290.4	116
		C	4020	675	2205	14400	1575	200	22124		5973.7	83
	B	V	144	5	45	462	3	1	496	153	100.8	74
		C	18720	1060	2655	13575	3825	180	44640		6352.8	61
Feb.	A	V	180	18	21	497	6	2	447	175	87.8	56
		C										243
	B	V	1232	914	68	781	2	1	3540	1417	325.1	351
		C										219
Mar.	A	V	97	24	20	443	7	1	349	196	71.5	86
		C										41
	B	V	115	21	66	1103	5	1	226	148	115.1	102
		C										312
Average	A	V									79.7	64.5
		C									4715.9	162.5
	B	V									104.7	179.6
		C									4784.7	175.7

TABLE II

Comparison of bacterial count of vanilla ice cream with that of average milk. Results are given for 1/75,000 cc in each case.

Kind of Organism	Average milk	Ice Cream Company A	 Company B
Diplococci	25-50	188	388
Short Streptococci	0-6	33	127
Long Streptococci	0-3	33	41
Staphylococci	0-6	435	562
Isolated rods	0-1	1.8	3.5
Total number of bacteria	25-125	1063	1396
Number of groups	6-40	189	279
Average number bacteria per group	1.5-3	5.6	5

SPECIES OF TOLYPELLA IN NEBRASKA

By Fay Kenoyer Daily

In 1944 when "The Characeae of Nebraska" was published by the author (1), the genus Tolypella was not represented in the collections or reports. Subsequently, however, three species were found by Dr. Walter Kiener who has collected widely in that state, and it is with the description and illustration of these that the present paper is concerned.

The author wishes to thank the following: Dr. Walter Kiener of the Game, Forestation and Parks Commission of Nebraska for untiring collection and generous distribution of excellent Charophytes; Dr. Frances Drouet of the Chicago Natural History Museum for generous loan of specimens.

Duplicate specimens may be found in the herbaria of the University of Nebraska, Butler University, and the author. Other specimens will be distributed.

Although some variation was noted in the species of Tolypella described and illustrated here, it is considered better to postpone varietal or sub-species splitting until a much greater number of American specimens have been observed.

Macroscopically, the Tolypellae are recognized by the dense fruiting heads fringed with diversely projecting branchlet ends of varying length. Keys to genera and species follow:

KEY TO THE GENERA OF THE CHARACEAE OF NEBRASKA

Coronula of the oogonium having five cells in one series. Mature oospore terete.................................Chareae
    Antheridium below oogonium. May or may not be corticate.................................Chara
Coronula of the oogonium having 10 cells arranged in two superimposed series of 5 cells each. Branchlets usually furcate, mature oospore either laterally compressed or terete ....Nitelleae

Antheridia apical at the furcation of the branchlet. Oogonia produced below the antheridia. Mature oospore laterally compressed. . . Nitella

Antheridia lateral at branchlet furcation. Antheridia may appear surrounded by oogonia. Mature oospore terete. . . . . Tolypella

KEY TO THE SPECIES OF TOLYPELLA OF NEBRASKA

Sterile branchlets divided. Coronula persistent. . 1. *Tolypella intricata*

Sterile branchlets undivided

Lateral and ultimate rays considerably attenuated. Coronula persistent. Outer membrane of oospore not decorated. . . . . 2. *T. prolifera*

Lateral and ultimate rays not much attenuated. Coronula evanescent. Outer membrance of oospore with linear granulations. . . . . . 3. *T. glomerata*

TOLYPELLA INTRICATA Leonh. in Lotos XIII:32. 1863.

Plate I-A

HABIT: about 10-15 cm. in height, loosely spreading sterile verticels, but fertile verticels are tangled "nests" with tips of larger branchlets appearing above tangled shorter accessory branchlets. MONOECIOUS. STEM: about 1.5 mm. wide. STERILE BRANCHLET: 6-7 in a verticel; central ray with 1 or 2 nodes producing 2 or 3 lateral rays; topped by a 3-4 celled, attenuate, ultimate ray; lateral rays may also bear 2 or 3 lateral rays, in which instance they also have a 3-4 celled ultimate ray; lateral rays usually 3-4 celled; ultimate cells usually short and more or less acute, but may be elongated and rounded as if the end cell had either not been formed or had fallen off leaving the penultimate cell. FERTILE BRANCHLET: variable in size, 6-7 large ones accompanied by numerous small accessory branchlets in a verticel; central ray may produce 2 or 3 nodes bearing 3-4 lateral rays; topped by a 3-4 celled ultimate ray; lateral rays branching from the first node of the central ray may bear 1 or 2 nodes also producing lateral rays; lateral rays branching from the central ray at the second node may also bear a node producing lateral rays if the central ray has 3 nodes; however, if the central ray has only 2 nodes, lateral rays at the second node are simple; lateral rays at the third node on the central ray are usually simple; ultimate and lateral rays attenuate, 2-4 celled; ultimate cell of lateral and ultimate rays may be more or less short and acute or extended and rather blunt appearing as if the end cell had either not been formed or had fallen off. Oogonium: may be produced at the base of the verticel and on the nodes of the central and lateral rays of the fertile branchlet; coronula persistent, cells of lower tier about 0.015 mm. high, cells of upper tier about 0.022 mm. high, cells about 0.015 mm. broad. Oospore: about 0.371 mm. long and 0.318 mm. broad, light brown, having 10 or 11 prominent and often winged ridges; outer membrane of oospore light yellow, translucent, very thin and flexible, granulate. Antheridium: about 0.238 mm., usually sessile. Specimen seen: Douglas county; Carter lake, Omaha, *Walter Kiener 20011,* April 26, 1946.

TOLYPELLA PROLIFERA Leonh. in Lotos XIII:57. 1863.
Plate I-B

Habit: much branched from main stem resembling a tree superficially, about 10-15 cm. in height with fruiting verticels contracted into dense heads or "nests," incrusted. Monoecious. Stem: about 1-1.5 mm. broad. Sterile branchlet: variable in number in a verticel (from 6-16 in plants studied), simple, elongate, 2-5 celled, attenuate; ultimate cell more or less short and acute, but may be rather elongate and blunt as if the end cell had either not been formed or had fallen off—see Migula (2). Fertile branchlet: crowded into a tangled verticel, usually shorter than the sterile ones; central ray may produce 1 or 2 nodes, terminated in an ultimate elongated ray of 2-5 cells, at each node about 3 smaller 2-4 celled lateral rays are produced which may occasionally bear also a node with lateral leaflets; ultimate and lateral rays may produce a more or less acute ultimate cell, but it may also be elongate and blunt as in the sterile branchlets. Oogonium: produced at the base of the fertile verticel and on the nodes of the central and lateral rays of the branchlet; coronula of oogonium persistent, about 0.040 mm. high with cells of the upper tier 0.025 mm., cells of the lower tier about 0.015 mm. and about 0.020 mm.-0.025 mm. broad at the widest point; spiral cells of oogonium elongated considerably in the specimen illustrated, they also secreted a lime shell around the oospore. Oospore: 0.318-0.371 mm. long, 0.265-0.292 mm. wide, tan, 9 or 10 prominent ridges, outer membrane light tan, not decorated, thin translucent. Antheridium about 0.318 mm., either sessile or stalked. Specimens seen: Buffalo county: Loup river pond, south of Ravenna, *Walter Kiener 20195,* May 3, 1946. Lincoln county: roadside ditch on floodplain, North Platte, 9 miles east, *Walter Kiener 18772,* April 1945.

TOLYPELLA GLOMERATA Leonh. in Lotos XIII:129. 1863.
Plate I-C

Habit: small, fruiting verticels in dense heads. Monoecious. Stem: simple, about 0.8 mm. broad. Sterile branchlet: 6 or more of varying length in a verticel, 2-3 celled; ultimate cell not much narrower and shorter than basal cell. Fertile branchlet: crowded into a compound head of many verticels; with 1 node bearing 2 or 3 simple, incurved, short lateral rays and topped by an elongated ultimate ray; lateral and ultimate rays 2 or 3 celled, not much attenuated, ultimate cell usually long and rounded. Oogonium: sometimes stalked, found at the base of the fertile verticel and at the branchlet node; coronula deciduous, cells of upper tier about 0.025 mm. high, cells of lower tier about 0.020 mm. high, cells at widest point about 0.025 mm. Oospore: orange brown, 0.318-0.371 mm. long, about 0.265-0.300 mm. broad, with 7-8 low ridges; outer membrane light brown, decorated with linear granulations, thick, somewhat rigid and opaque. Antheridium: either stalked or sessile, 0.371-0.398 mm. Specimen seen: Kearney county: gravel pit pond, Platte river, north of Axtell, *Walter Kiener 18965,* May 23, 1945.

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The Herbarium
Butler University

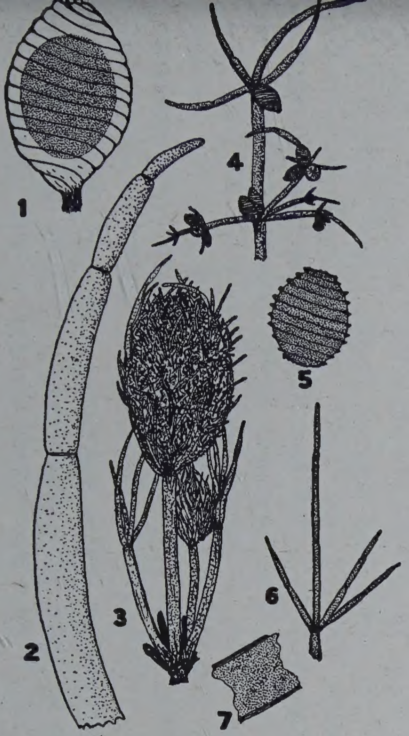

Plate I-A

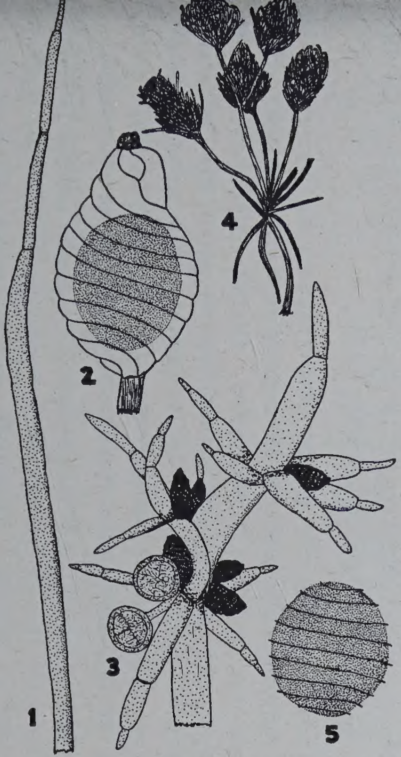

Plate I-B

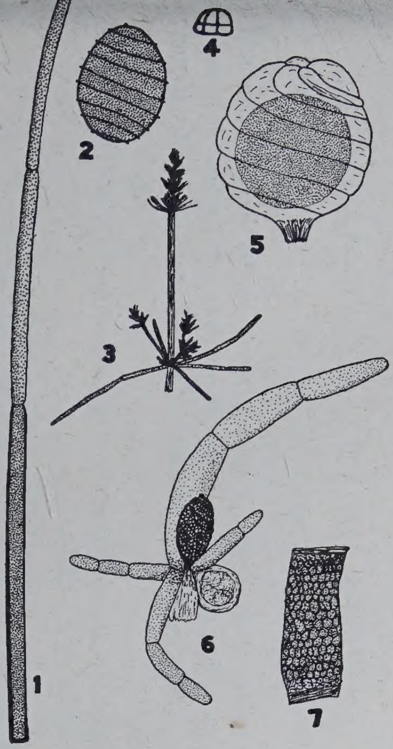

Plate I-C

I-A. Tolypella intricata Leonh. 1. Oogonium. 2. Ultimate ray of branchlet. 3. Portion of plant, natural size. 4. Fertile branchlet. 5. Oospore. 6. Sterile branchlet. 7. Portion of outer membrane of the oospore.

I-B. Tolypella prolifera Leonh. 1. Sterile branchlet. 2. Oogonium. 3. Fertile branchlet. 4. Portion of plant, ½ natural size. 5. Oospore.

I-C. Tolypella glomerata Leonh. 1. Sterile branchlet. 2. Oospore. 3. Plant, natural size. 4. Coronula. 5. Oogonium. 6. Fertile branchlet. 7. Portion of outer membrane of the oospore.

NOTES ON THE ALGAE—I, II

By William A. Daily

Specimens cited here are to be found in the writer's personal herbarium which is on file in the Herbarium of Butler University and the Cryptogamic Herbarium of the Chicago Natural History Museum.

I gratefully acknowledge the suggestions and aid of Dr. Francis Drouet and Fay K. Daily.

MYXOPHYCEAE—I

Johannesbaptistia pellucida (Dickie). Taylor & Drouet, Bull. Torrey Bot. Club 65:285-292. May, 1938.

In North America, this peculiar alga heretofore has been reported found only in saline and subsaline pools along the coasts. This specimen was found in a planktonic collection from Lake Wehi, Wayne county, Indiana, an artificial fresh-water lake of some 40 years of age. The alga is not as abundant in number of plants as is found in the saline habitats, but it is hoped that future collections from fresh-water bodies of water will prove otherwise.

For a taxonomical and morphological discussion of this interesting alga, see F. Drouet, "Notes on Myxophyceae I-IV," Bull. Torrey Bot. Club. 65:285-292. May 1938, and F. Drouet, "Myxophyceae of the G. Allan Hancock Expedition of 1934," collected by William R. Taylor. Univ. Calif. Publ. Hancock Pacific Exped. 3:16, pl. 2, f. 3, 4 (1936). Frémy, Pierre. 1935. 'Trois Cyanophycées nouvelles de l' afrique du Nord." Bull. Soc. Hist. nat. Afr. Nord. 26:89-101. Frémy, P. & De Toni, Giuseppe. 1940. "Osservazioni intorno al valore sistematico del genere Johannesbaptistia G. de Toni 1934 P. Fémy 1935 emend. (Cianoficee)." Estratto dagli Atti Del Rea Le Instituto Ueneto Di Scienze, Lettere Ed Arti Anno accademico 1939-40. vol. 99. Part II: Ce. di Scienze mat. e nat.

Professor Pierre Frémy and Giuseppe De Toni (loc. cit.), suggest that the genus Johannesbaptistia G. De Toni 1934, P. Frémy 1935 emend. is but a growth-form of *Lyngbya lutea* Gomont. The latter species does not occur in the Lake Wehi collection. I agree with Dr. F. Drouet that *Johannesbaptistia pellucida* (Dickie) Taylor and Drouet be allowed to stand appended to the Chroococcaceae.

The filaments are solitary, straight or tortuous and composed of a single row of protoplasts. The filaments vary in width from 6 to 14 microns. The discoid protoplasts are blue-green, 5 to 9 microns wide, 2 to 4 microns long, homogeneous to slightly granular. The protoplasts often have the appearance of being in pairs, but soon become separated from each other by sheath material. The gelatinous sheaths and matrix appear to be unstratified. Fig. 1. Drawn from herbarium specimen.

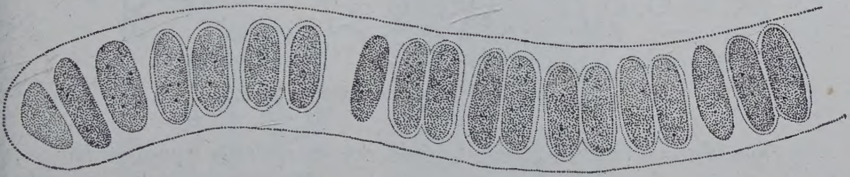

Fig. 1. *Johannesbaptistia pellucida* (Dickie) Taylor and Drouet.

Other species in the collection from Indiana are *Chroococcus turgidus* (Kütz.) Nag., *Merismopedia tranquilla* (Ehrenb.) Trevis. and Ceratium sp. Specimen seen: Indiana: Wayne county: A plankton collection with debris from bottom of Lake Wehi, ½ mile south of Germantown, F. K. & W. A. Daily *1185,* July 16, 1944.

BORZIA TRILOCULARIS COHN. ex Gom., Monogr. Oscill. 2: 118. 1893.

In the Butler Univ. Stud. 6: 84. 1943, the writer reported this species as a first report for Indiana. B. H. Smith cited this species previously in the Proc. Ind. Acad. Sci. 41: 183. 1931.

This species is extremely rare, and evidently the writer's collection remains the only available herbarium specimen in Indiana.

CHLOROPHYCEAE—II

PLATYDORINA CAUDATA KOFOID, Bull. Illinois State Lab. of Nat. Hist. 5: 419-440. 1899.

According to published reports, *Platydorina caudata* Kofoid heretofore has been found in California, Illinois, Iowa, Kentucky, Minnesota, Missouri, Ohio and Tennessee. Indiana is now added to that list.

The chief distinguishing characteristic of this genus from other Volvocaceae other than being a flattened horseshoe-shaped colony, is the presence of 3 to 5 conical projections at the posterior end. Fig. 2. Drawn from herbarium specimen.

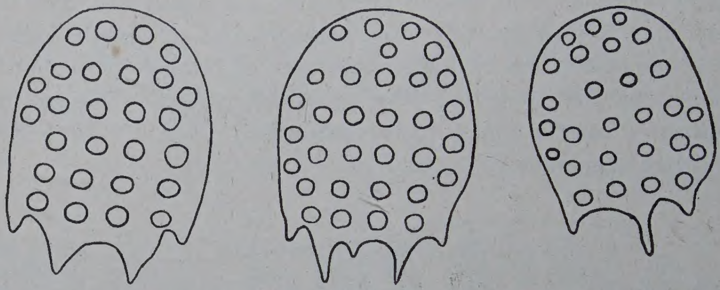

Fig. 2. *Platydorina caudata* Kofoid.

Specimens seen: Indiana: Carroll county: With *Lyngbya Birgei,* planktonic in Lake Freeman, Monticello, W. A. Daily *31,* July 23, 1938. Tow in Lake Freeman, Monticello, F. K. & W. A. Daily *1016,* Sept. 8, 1942.

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